SmartLab

Automated multipurpose X-ray diffractometer

Rigaku

POWERING NEW PERSPECTIVES

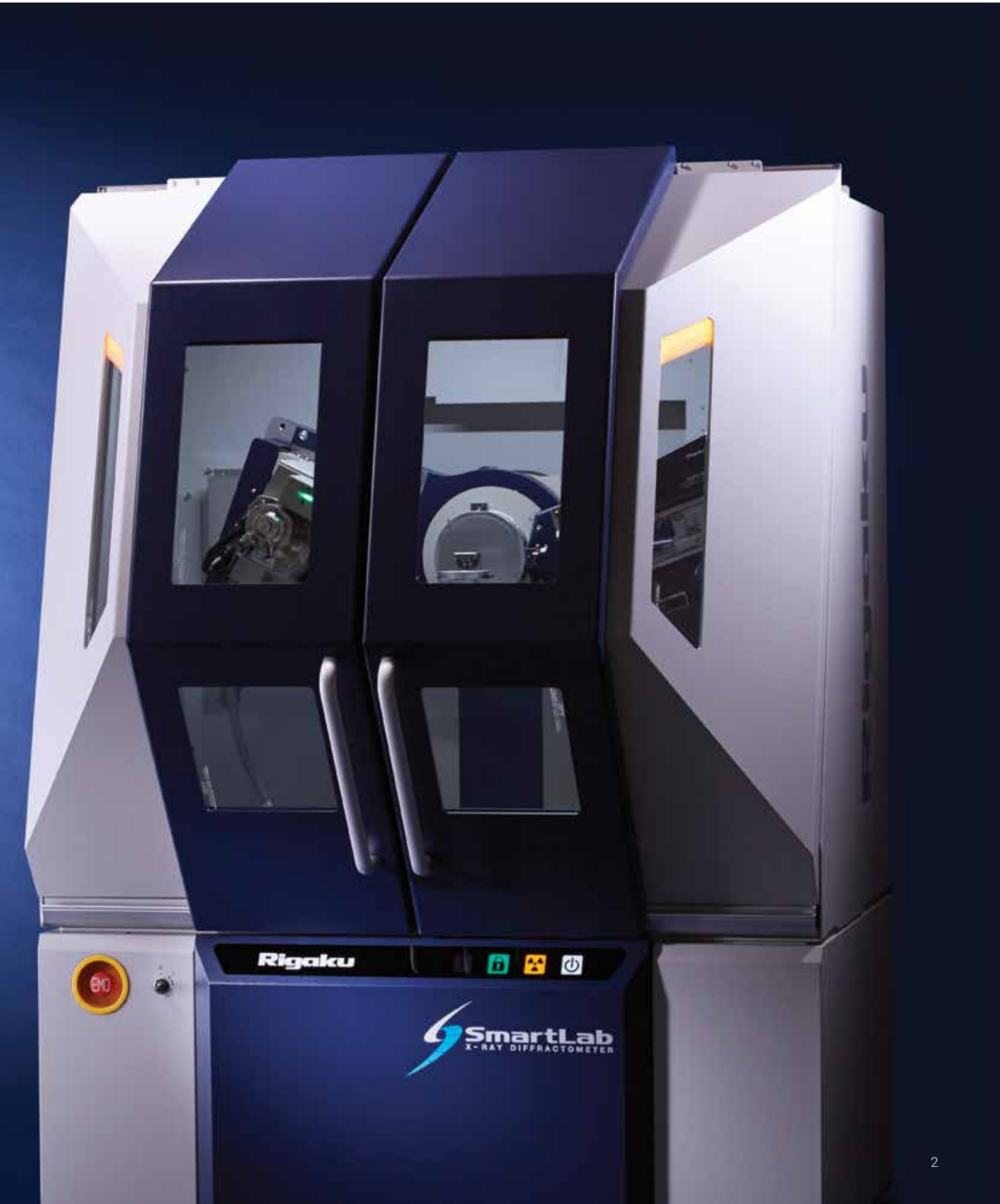
Leading With Innovation

Next generation Rigaku SmartLab® intelligent multipurpose X -ray diffractometer

A highly versatile automated X -ray diffraction (XRD) system, the newest SmartLab diffractometer offers continued refinement of the ease-of-use features that enabled the original SmartLab diffractometer to receive the coveted R&D 100 Award, such as automatic alignment, component recognition, Cross Beam Optics and a 2D detector. SmartLab began as the flagship model from Rigaku in 2006 and new leading-edge, advanced technologies have been continuously introduced over the years. This newest addition to the SmartLab series of high-resolution X-ray diffraction analyzers is engineered to provide the best performance in all X -ray diffraction or scattering applications by offering not only breakthrough hardware, but also advanced "User Guidance" functionality within the new SmartLab Studio II software, to establish a new industry standard for multipurpose X -ray diffractometers.

Key features and benefits of the new SmartLab include :

- Highest flux X-ray source: PhotonMax
- HyPix-3000 high energy resolution 2D detector
- New CBO family, with fully automated beam switchable CBO-Auto and high-resolution micro area CBO-μ
- Various *operando* measurements with the new SmartLab Studio II


Rigaku
EMO
SmartLab
X-RAY DIFFRACTOMETER

High-performance X-ray source

PhotonMax

The new generation rotating anode, PhotonMax, reduces the X-ray generator's environmental footprint, although it still produces 9 kW of high-power X-rays. The flux generated by the PhotonMax is about 5 times greater than a conventional sealed X-ray tube loaded at 1.8 kW. This enables you to see the fine details of your sample within a reasonable measurement time. The PhotonMax has a newly designed anode that provides more than 3 times longer lifetime than its predecessor. This maximizes the uptime of the instrument and minimizes the cost of ownership while reducing the environmental footprint.

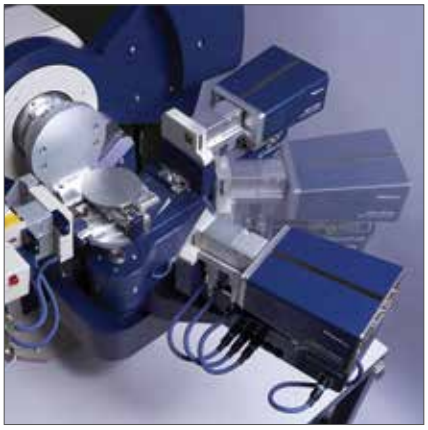
Specifications	
Output	9 kW
Focus	Fine focus
Target material	Cu, Co, Cr, Mo
Long lifetime target is adopted.	

A new mechanical seal has been introduced to substantially improve the lifetime of the target.

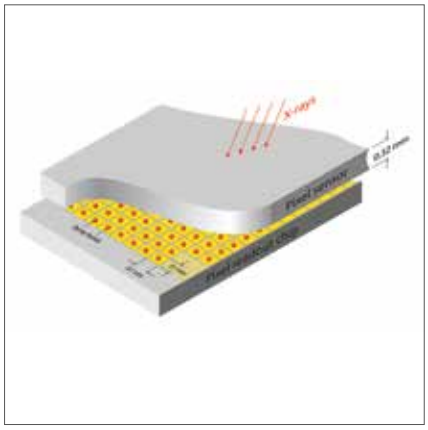
Leading-edge hybrid pixel array detector

- Supports 0D, 1D and 2D measurement modes
- Excellent energy resolution to suppress XRF
- Keeps background noise to an absolute minimum
- Wide dynamic range
- Shutterless measurement
- Maintenance free

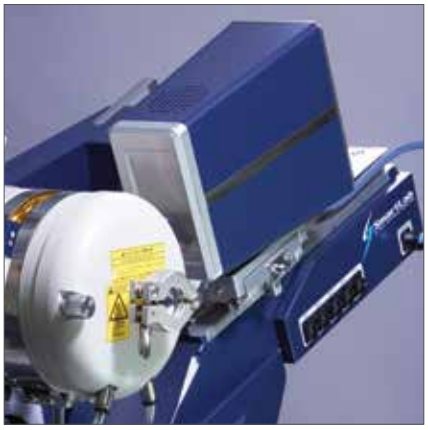
Active area	2,984 mm^2 (77.5×38.5 mm)
Pixel size	100 µm × 100 µm
Number of pixels	775 × 385 = 298,375 pixels
Global count rate	>2.9 × 10^{11} (>1×10^6 cps/pixel)
Efficiencies	Cr, Co, Cu: ~99% Mo: ~38%
Energy resolution	40% better than previous type



Fully compatible with 5-axis goniometer design



Hybrid pixel array detector (HPAD) design



Shutterless high-speed *in-situ* measurement

*This product was jointly developed by Department of Measurement and Electronics, AGH University of Science and Technology (Poland) and Rigaku Corporation.

Achieve excellent energy resolution

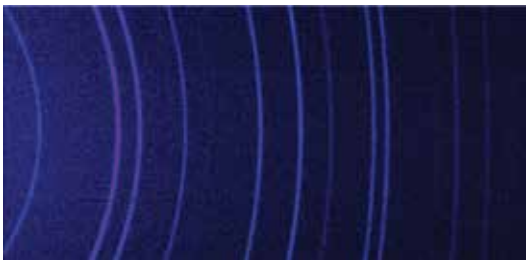
X-ray fluorescence background emitted by samples makes it difficult to detect minute peaks or scattering signals from amorphous components. It may also impede the correct calculation of the intensity of any detected peaks.

Unnecessary X-ray fluorescence can be removed using a monochrometer placed between the sample and the detector. For two-dimensional (2D) measurement intended to detect Debye rings, however, no optical system can be inserted between the sample and the detector.

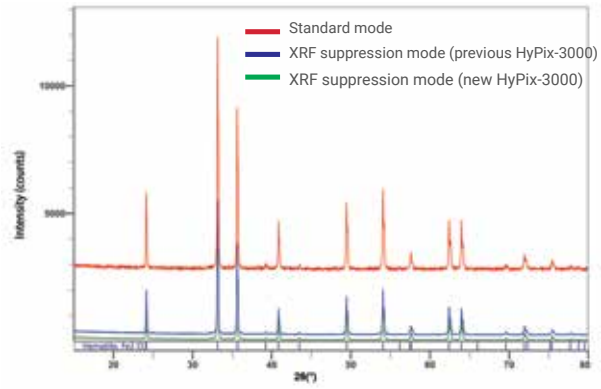
For the removal of X-ray fluorescence during 2D measurement, a mode in which the energy resolution of the detector can be used to disable counting of unnecessary X-ray fluorescence is available.

The excellent energy resolution greatly contributes to background suppression.

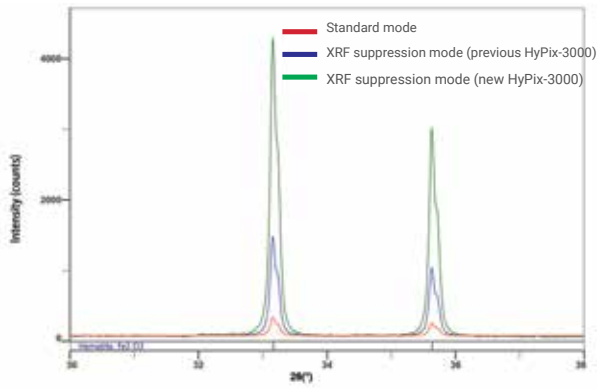
2D diffraction image measured in standard mode



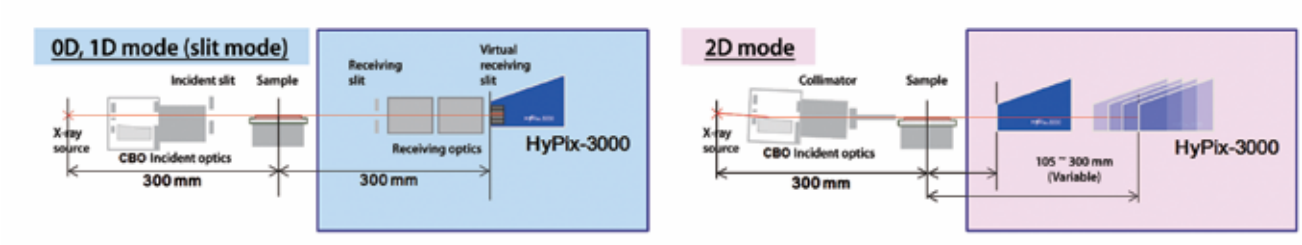
2D diffraction image measured in XRF suppression mode



1D diffraction pattern obtained by standard mode, XRF suppression mode (previous HyPix-3000) and XRF suppression mode (new HyPix-3000)



A graph of the same data as in the left figure normalized by the background noise intensities

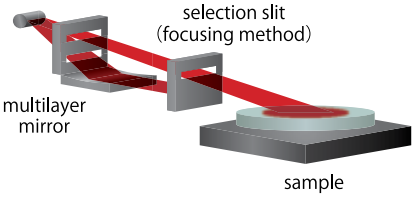


HyPix-3000 functions not only as a 2D detector but also as a 0/1-D detector. All applications can be handled with this single detector, eliminating the inconvenience of preparing and switching individual detectors for different applications.

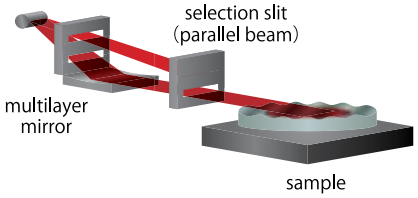
Optical configurations for various applications

CBO (Cross Beam Optics)

CBO

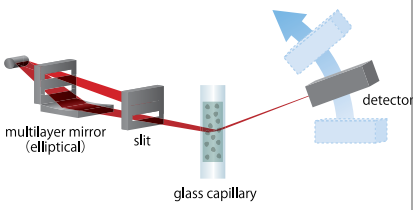


Divergent beam



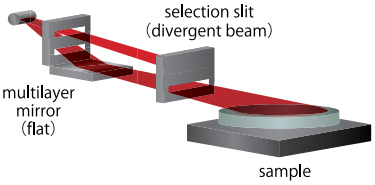
Parallel beam

CBO-E



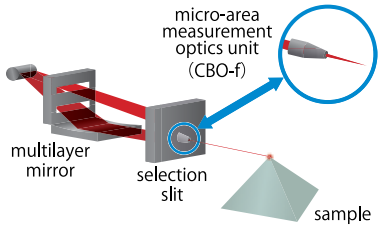
Divergent beam/convergent beam

CBO-α



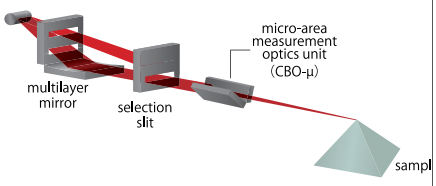
Divergent beam
(High intensity, low background noise)

CBO-f



Converges line beams
to a minute point of ≈400 μm.
No need to change the X-ray tube focus.

CBO-μ



Converges line beams to a high-intensity
minute point of ≈100 μm.
No need to change the X-ray tube focus.

Detectors

D/tex Ultra250/250HE

1D semiconductor detector D/tex Ultra250/250HE	
Active area	384 mm^2 (19.2×20 mm)
Spatial resolution	75 μm
Global count rate	2.5 × 10^8 (1×10^6 cps/strip)
Efficiencies	Cr, Co, Cu: ~99% Mo: ~40%, ~70% (250 HE)

HyPix-400*

Multidimensional semiconductor detector HyPix-400*	
Active area	369 mm^2 (9.6×38.5 mm)
Pixel size	100 μm × 100 μm
Global count rate	>3.7 × 10^{10} cps (>1×10^6 cps/pixel)
Efficiencies	Cr, Co, Cu: ~99% Mo: ~38%

*This product was jointly developed by Department of Measurement and Electronics, AGH University of Science and Technology (Poland) and Rigaku Corporation.

CBO-Auto: Fully automatic switch between reflection and transmission optics and geometries

Reflection mode

The optimal measurement method depends on the type of sample or the application.

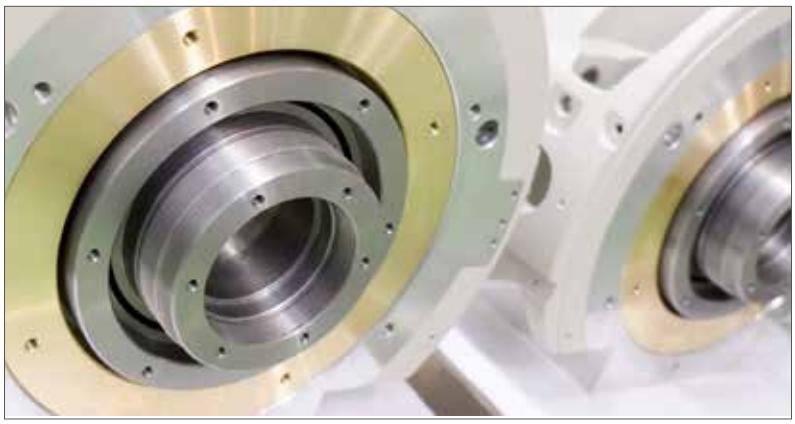
The Bragg-Brentano focusing (reflection mode) is the standard measurement method for generic powder samples. For samples with specific orientation or large grains (i.e., powder, solid, or films), the transmission method is the optimal approach.

SmartLab provides fully automatic switching between the reflection and transmission methods.

Transmission mode

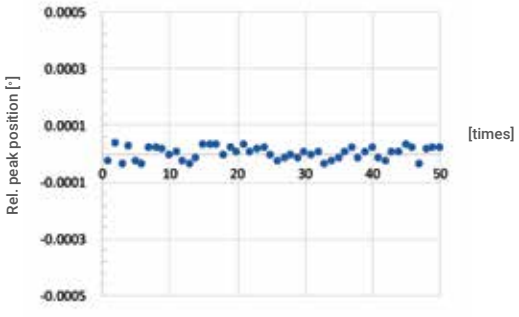
CBO-Auto	
Ts axis	Automatic control
Optics	CBO-E (Cu) / CBO-E (Mo)
Sample stage	Reflection/transmission ASC-6

High-precision goniometer with optical encoders



Encoder controlled high-precision goniometer	
Type	Vertical goniometer with sample horizontal mount
Goniometer radius	300 mm (0D, 1D), 150 - 300 mm (2D)
Minimum step size	0.0001°

Reproducibility of the peak positions



Peak position stability after 50 times repeat of 2θ–ω scan or *004* diffraction of silicon single crystal substrate. Distribution is within the range of reference accuracy ±0.00004°.

Designed for functionality and safety

Shutter CLOSE lamp

Shutter OPEN lamp


X-rays on lamp

EMO button


Interlock


Main key


LED light


Error lamp


Door lock lamp


Generator on lamp


Power on lamp

- **Safety-friendly enclosure design**
  - Leakage X-ray dosage 0.1 μSv or less
  - Safe interlock mechanism mounted even in case of erroneous operation
- **Design based on ergonomics**
  - Easy access to sample position
  - Wide door opening improves accessibility to the inside of the device, which allows smooth changing of attachments
- **High visibility design**
  - Six wide-angle windows let users check the state of the sample from various angles
  - Indicator for easy confirmation of equipment status
  - An easily recognizable LED lamp system has been adopted

SmartLab Studio II software suite

SmartLab Studio II is an integrated software platform with all functions from measurement to analysis.

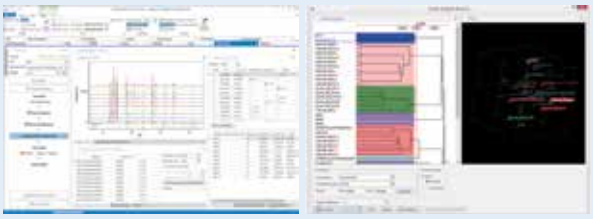
Selection of sample type,
Auto selection of measurement program

Optics change guidance/
(Auto optics adjustment)

Typical applications

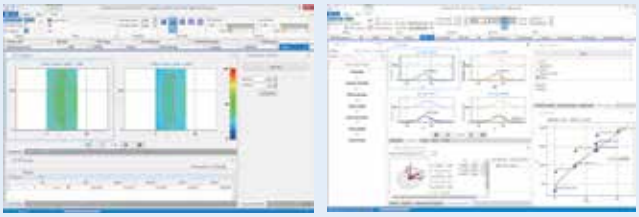
Powder

- Phase identification
- Quantification
- Crystallite size and distortion
- Precise lattice parameter determination
- Percent crystallinity
- Indexing
- Structural determination
- Precise crystalline structure determination

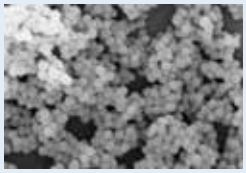


Stress

- $Sin^2\psi$ method
- 2D method
- Multiple-HKL method



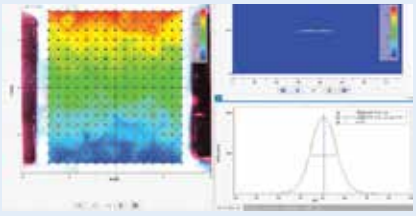
Small Angle Scattering (SAXS)



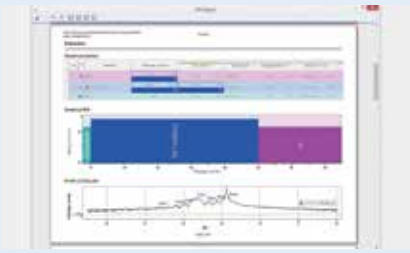
- Grain size distribution
- Pore size distribution
- Long period

Micro area measurement

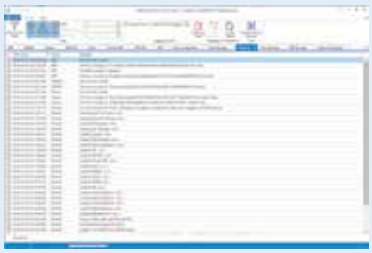
Specifications of beam size	
Collimator optics	50 µm to 1 mm
CBO-f	400 µm
CBO-µ	100 µm
No need to change X-ray tube focus	



Measurement, data processing, analysis

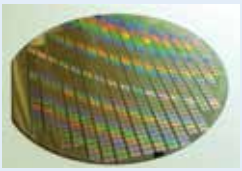


Reporting

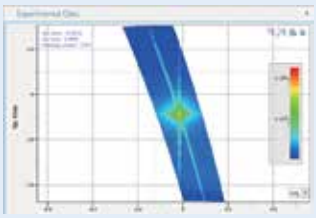


Control/analysis history view

Thin Film

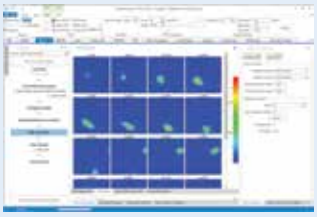


- Film thickness
- Density
- Roughness
- Composition



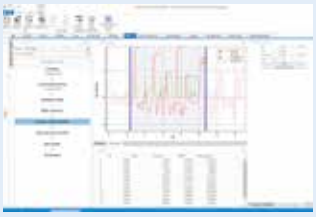
Texture

- Pole figure
- Stereographic projection
- ODF calculation
- Reverse pole figure



Radial Distribution PDF

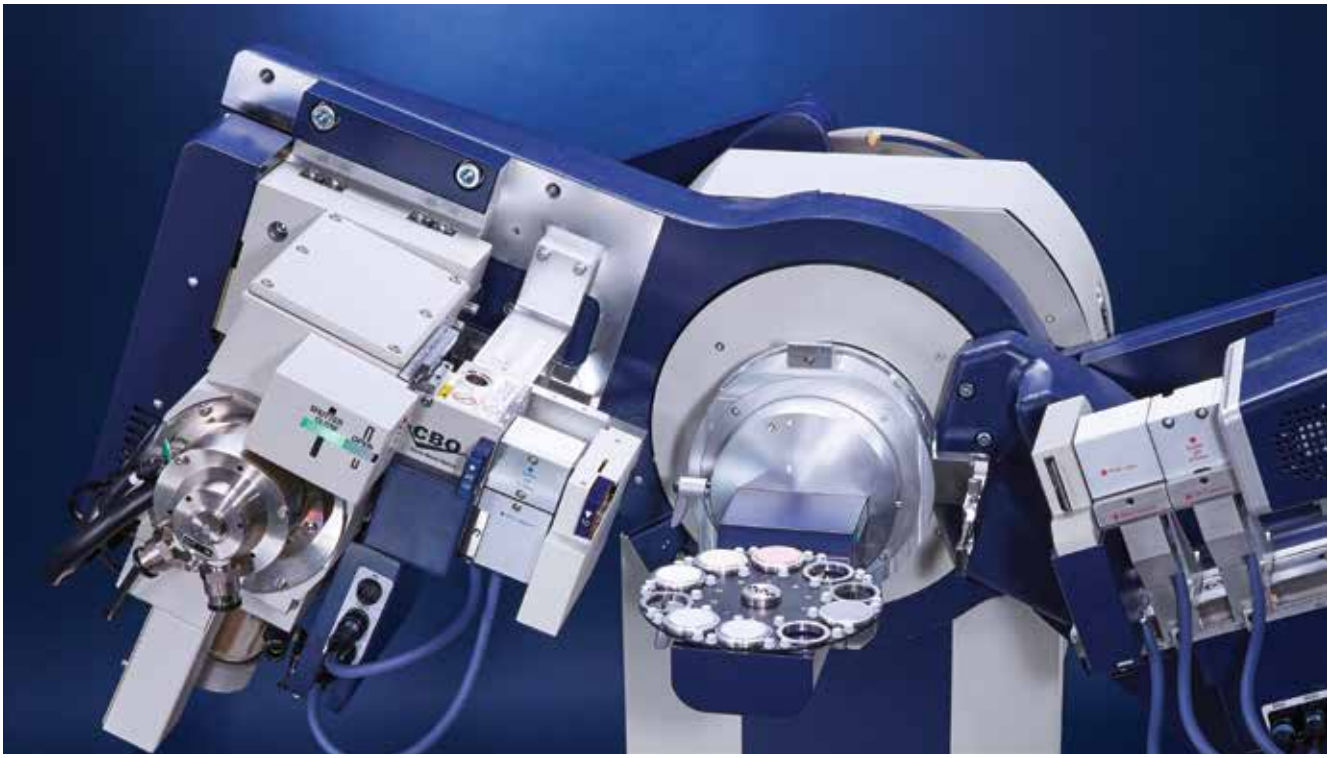
- PDF calculation
- Simulation



Large samples stage

Specifications	
Movable range	X-axis: -37~50 mm, Y-axis: -50~50 mm, Z-axis: -20~20
Min step width of each	0.001 mm
Max sample weight	20 kg

Advanced powder X-ray diffractometry

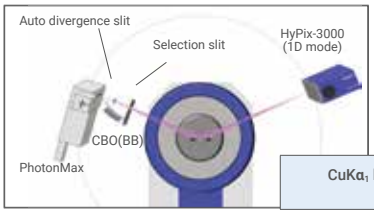


- Leading-edge 2D pattern direct qualitative analysis (2D-ID: 2D pattern phase identification).
- Seamless execution from qualitative analysis to Rietveld refinement.
- XRD data docking with DSC or other data.

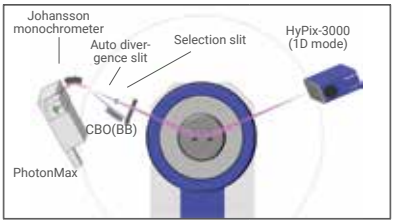
SmartLab Studio II Rietveld refinement

- Automatic input of required initial crystal structure from qualitative analysis result.
- Fitting with WPPF (Whole Powder Pattern Fitting) method.
- Crystallite size distribution analysis using FP (Fundamental Parameter) method.
- Estimation of oxidization state of metal atoms using BVS (Bond valence sum) method.
- Unknown crystal structure analysis package including from indexing to structure determination is available.

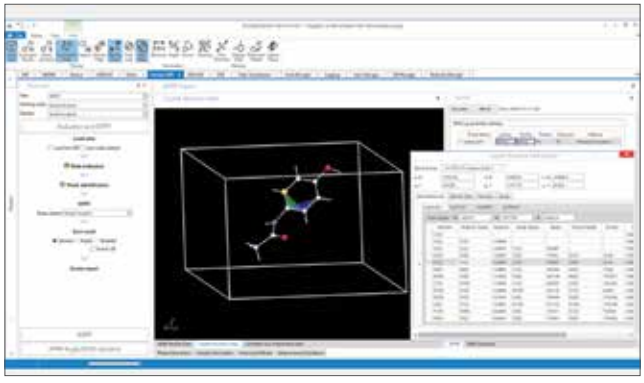
Bragg-Brentano focusing optics



$CuK\alpha_1$ high resolution optical configuration with Johansson optics



Cement qualitative analysis and quantitative analysis using Rietveld refinement



Organic powder precise crystalline structure determination

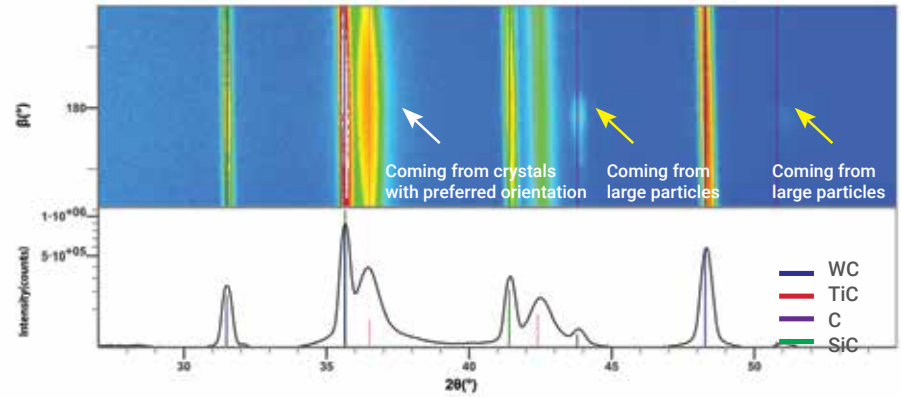
Advantage of qualitative analysis from 2D diffraction patterns

For powder X-ray diffractometry, samples are generally crushed into grains small enough to obtain ideal diffraction patterns. However, the crushing process may cause crystal phase transition. In addition, there is often a need to measure bulk or thin film samples without crushing.

For powders with large crystal grains (coarse particles) or with preferred orientation, the conventional powder measurement method may produce unreliable peak intensities or no observable peak at all, which has been a barrier to ensure reliable qualitative analysis.

The HyPix-3000 2D detector can be used to obtain 2D patterns for powder diffraction. These 2D patterns include distinctive features implying coarse particles or preferred orientation. These patterns can be processed to enable qualitative analysis in which the 2D pattern information is added to the 1D patterns.

Qualitative analysis of a carbide tool using 2D diffraction patterns



Pharmaceutical solutions

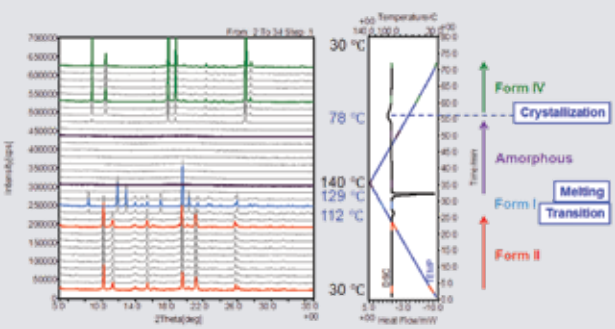
Compliance to FDA 21 CFR Part11

- High-level security
- Audit trail
- IQ/OQ/PQ
- Computer system validation

Validation document IQ/OQ/PQ

Electronic recording/signature (ER/ES) software

Unique XRD-DSC attachment

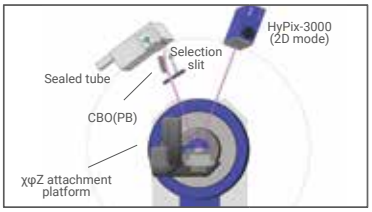


Simultaneous XRD-DSC measurement of tolbutamide (antidiabetic drug)

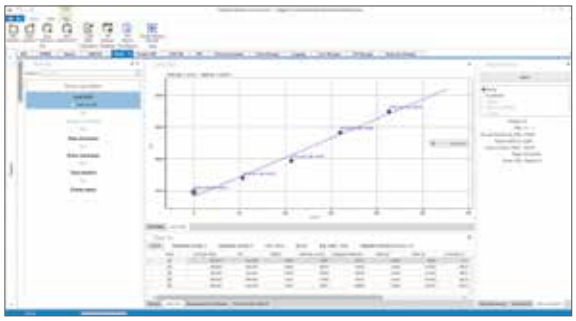
Residual stress analysis

- Wavelength can be selected for the type of metal or ceramics (Cr, Co, Cu, Mo).
- Supports $\sin^2\psi$, Multiple HKL and 2D (triaxial stress) methods. Analyses of thin films or materials with shear stress are available.
- Using micro area optics allows measurement of micro area stress mapping.

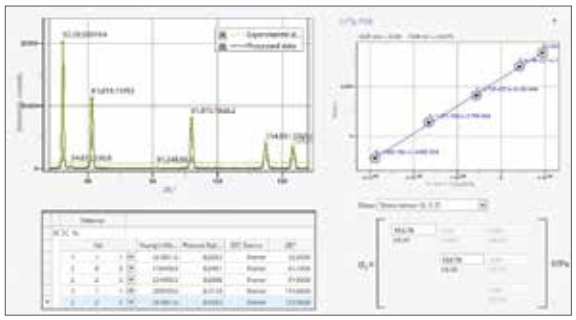
Residual Stress measurement optical configuration



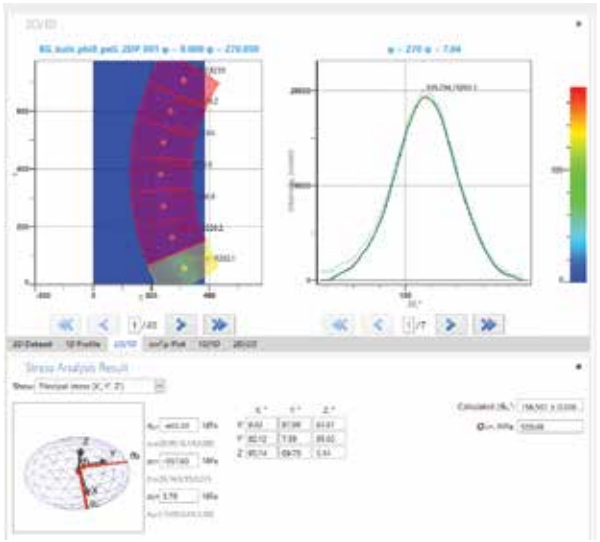
$\sin^2\psi$ method: Ni plate stress measurements



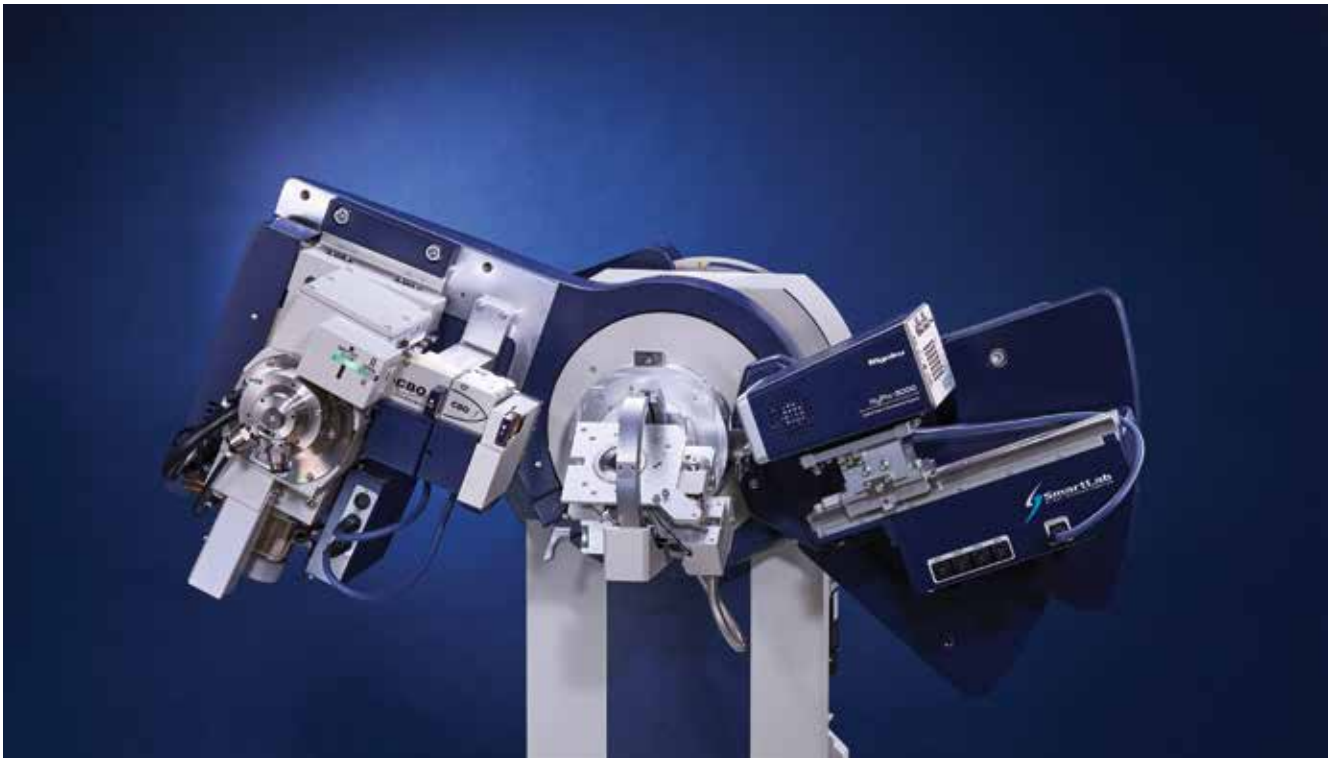
Multi HKL method: Ni thin film stress measurements



Triaxial stress: Shot peened steel stress measurements

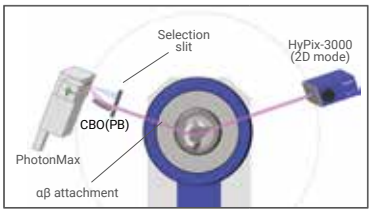


Pole figure and ODF analysis

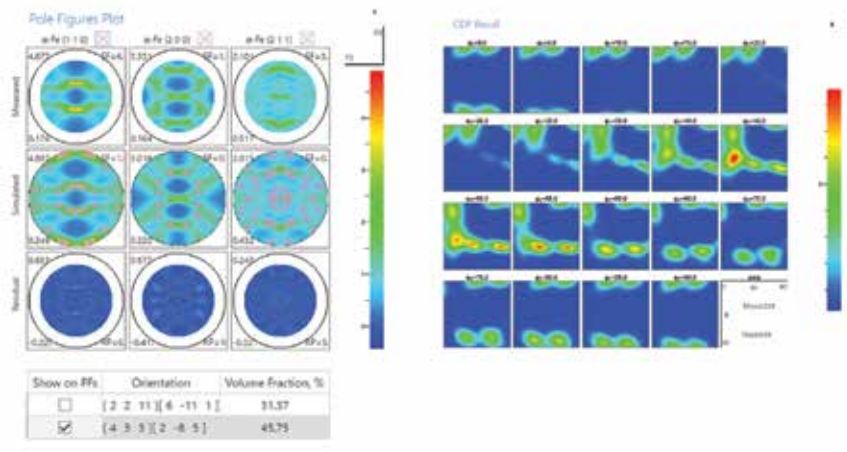


- In-plane or transmission measurement allows the acquisition of a whole pole figure.
- The α-β attachment allows γ rocking, alleviating the effect of large particles.
- With the use of a 2D detector, pole figures of two or more planes can be captured in a single measurement session.
- For analysis of complicated crystal texture, simulation analysis using not only pole acquisition but also ODF (Orientation Distribution Function) analysis allows calculation of the actual orientation distribution rate.
- Reverse pole figures can be used to determine the orientation of the lattice plane parallel to the sample surface.

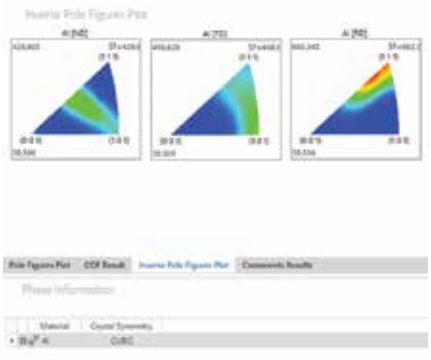
Pole figure measurement optical configuration



SUS430 pole and ODF analyses

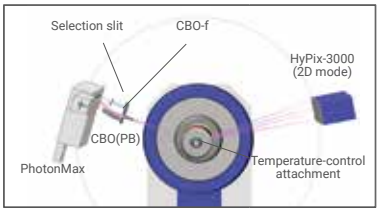


Reverse pole figures of aluminum foils



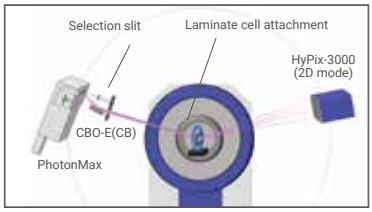
In-situ/operando measurements

Temperature-controlled measurement optical configuration



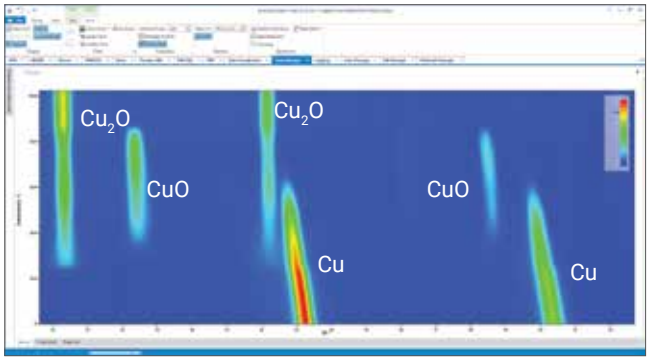
- HyPix-3000 detector measures 30° range of 2θ in a single shot. It can repeat the shot every 0.1 s. minimum.
- The Reactor X achieves high-speed temperature increase with infrared heating. It can accept many different types of gas because the heater section is separated from the sample chamber.

Optical configuration with a laminate cell attachment

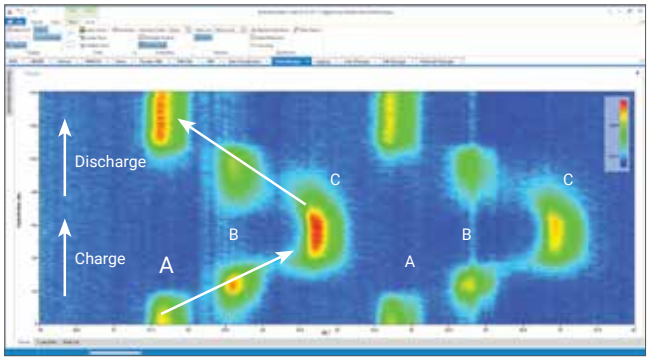


- A battery cell attachment for evaluation of charging/discharging, indispensable for battery material assessment, and a laminated cell attachment are available.
- Bulk data obtained from *in-situ*/operando measurement can be processed as a single unit by software. In addition, effective visual 3D diagrams can easily be created by adding a time axis to the angle/intensity axis.

Cu powder *in-situ* high-speed temperature increase measurement (300°/min) 2θ-temperature-intensity

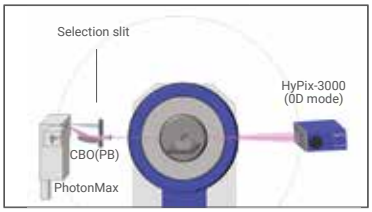


Li(Ni,Mn)O_4 operando charge/discharge measurement 2θ-time-intensity

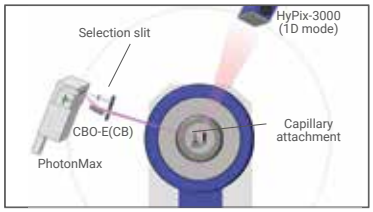


Nanomaterials analysis

SAXS measurement optical configuration



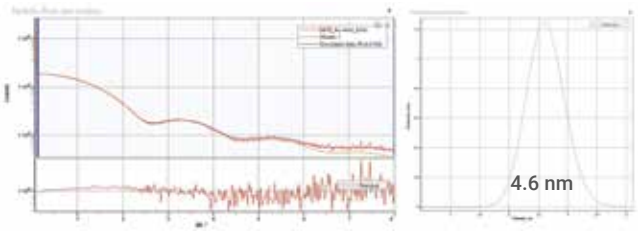
PDF measurement optical configuration



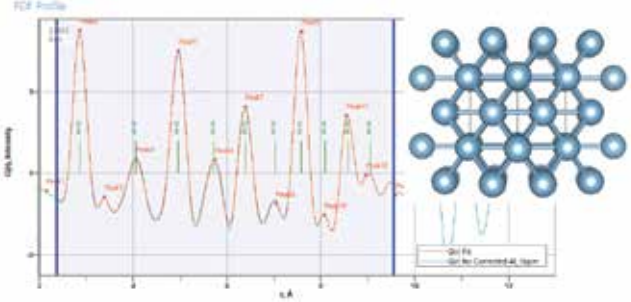
- SAXS can be used to analyze the grain size of a material (minimum 100 nm) and its distribution as well as the periodic structure. Furthermore, USAXS (Ultra SAXS) is also available, achieving measurement of minimum grain size of 1000 nm.

- PDF is an approach to derive real space information by inverse Fourier transformation of reciprocal space data. It can analyze interatomic distances, coordination number and periodicity irrespective of crystallinity of samples.

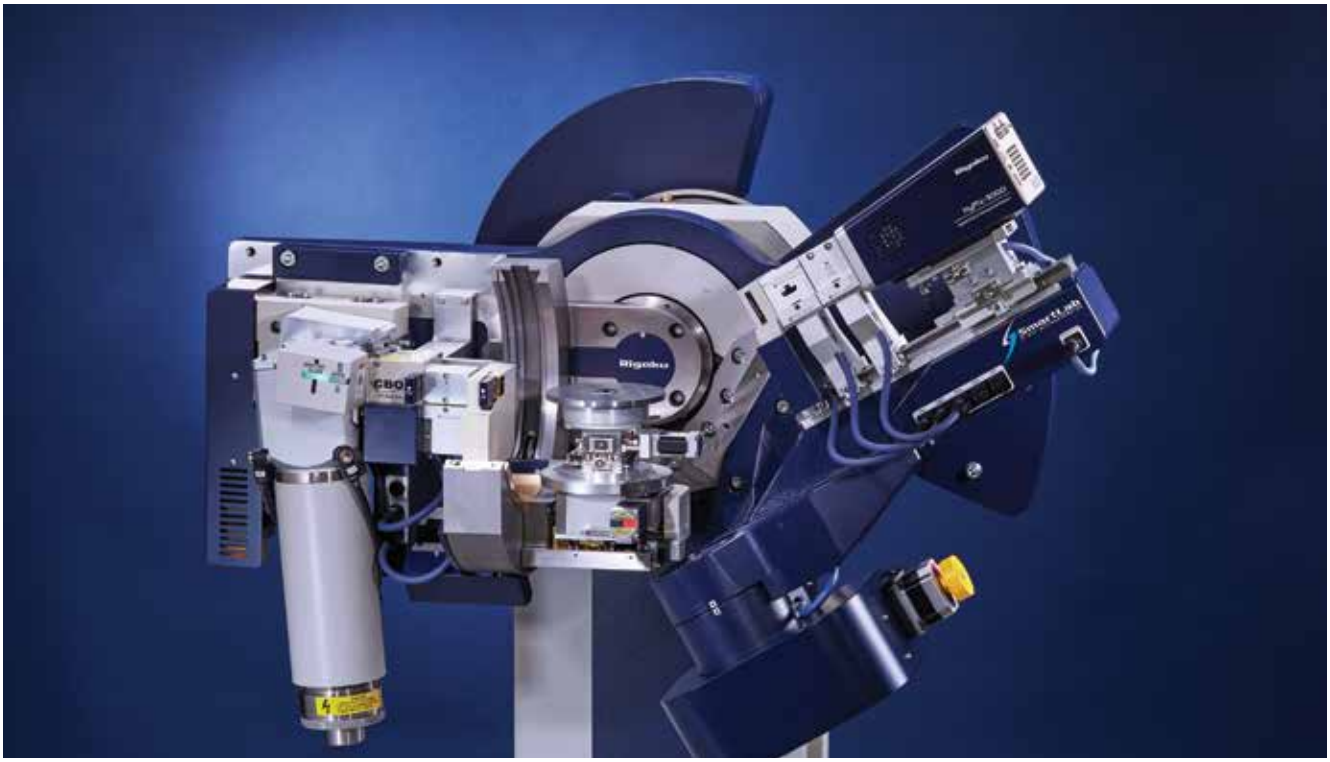
Au nanoparticle grain size and distribution analysis



PDF analysis of Al metal

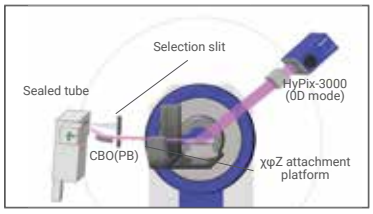


Advanced thin film analysis

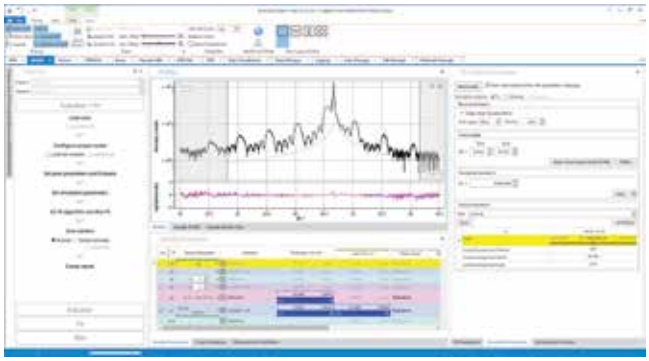


- A goniometer equipped with χ and φ axes as standard specifically designed for thin films is used to support the various measurements necessary for thin film analysis.
- Capable of obtaining thin film surface information by limiting the incidence angle to a micro angle.
- The CuKα_1 high-resolution parallel beam optics using Ge crystal mono-chrometer allows evaluation of single-crystal thin films including epitaxial films.
- High-resolution rocking curve (HRRC) measurement allows analysis of thin film structure information.

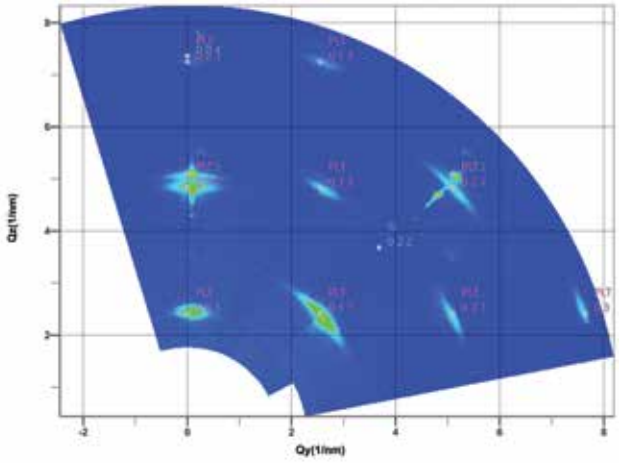
Out-of-plane measurement optical configuration



InGaN/GaN MQW thin film thickness analysis using HRRC

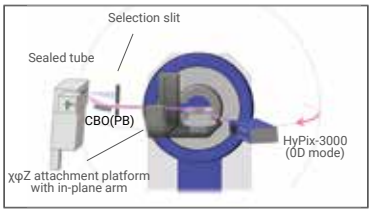


High-speed wide reciprocal lattice map measurement of ferroelectric thin films using 2D detector

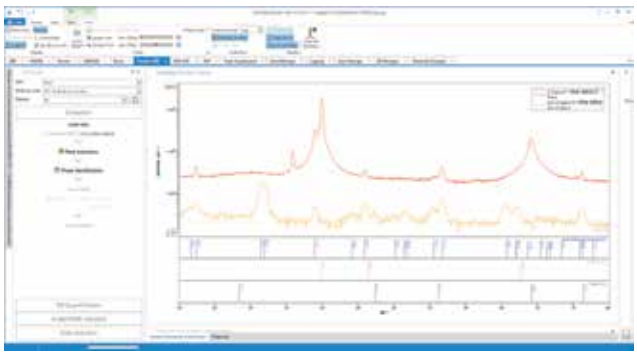


- Rigaku's original in-plane axes allow in-plane diffractometry with the X-ray incidence angle accurately controlled.
- Reciprocal lattice map measurement allows user to learn the orientation relationship between the substrate and the film as well as the crystalline state. The use of reciprocal lattice simulation allows user to easilydetermine the film condition.
- The 2D detector HyPix-3000 can be effectively used to obtain a wide reciprocal lattice map in a short time. The map is drawn in real time during measurement, resulting in a shorter analysis time.

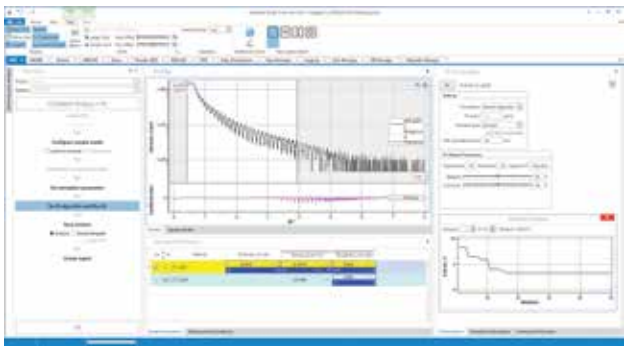
In-plane measurement optical configuration



Out-of-plane/in-plane measurement

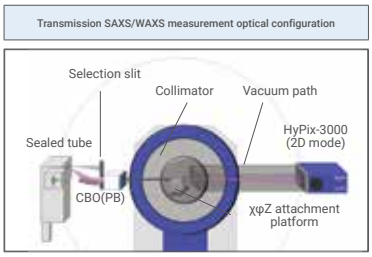


IGZO film thickness and density analysis using XRR

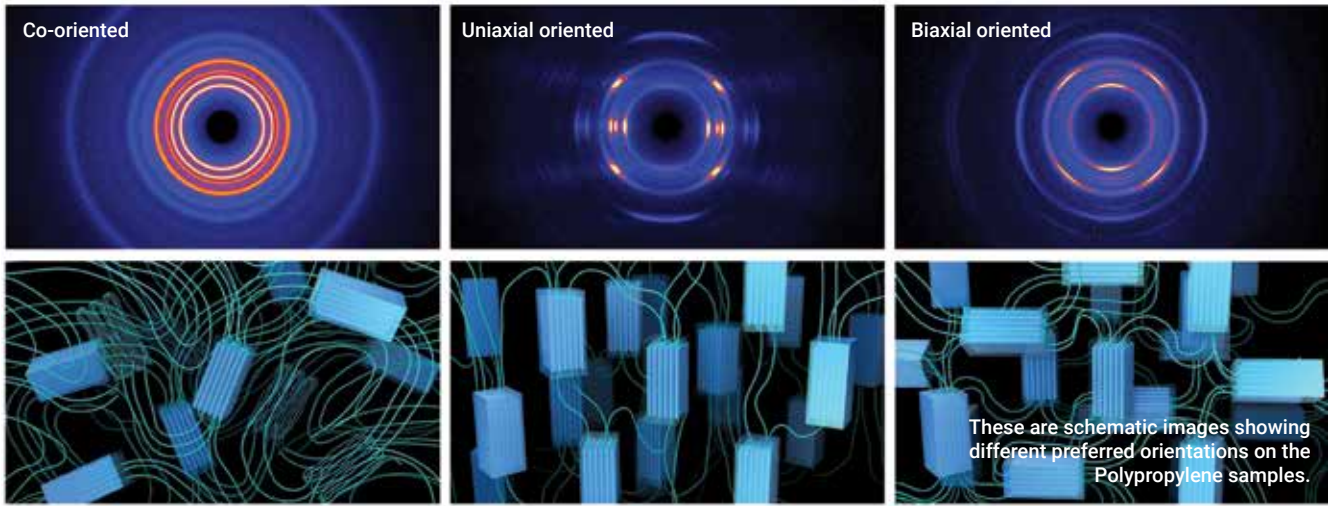


2D SAXS, WAXS and GI-SAXS

- Transmission 2D patterns of film materials can be measured. Circular measurement of Debye rings is available. This makes it easy to evaluate the oriented state and the degree of orientation.
- Transmission WAXS (Wide Angle X-ray Scattering) and SAXS (Small Angle X-ray Scattering) can be switched to obtain information including from long period structure to lattice level.
- With holders for different sample shapes, the equipment can accept powder, films and even textile samples, and provide mapping measurement within a sample. Measurement from the direction of the film cross section is also available.

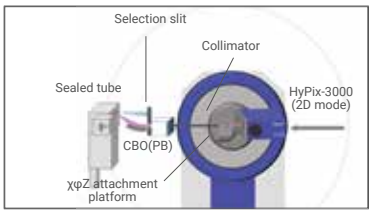


Preferred orientation of polypropylene observed y transmission 2D WAXS measurements

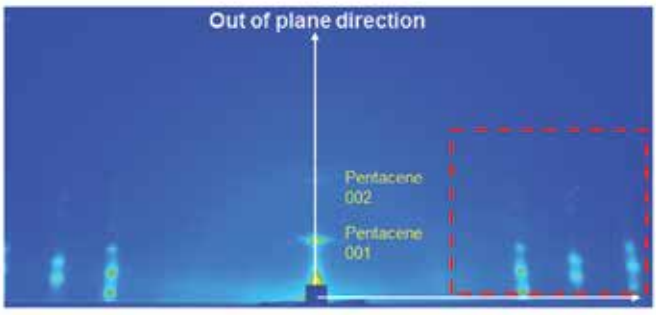


- The GI-SAXS/WAXS unit can be used for 2D measurement of thin film materials.
- A newly developed aperture slit (patent pending) allows even clearer profile capturing in the in-plane direction.
- Information in both the lamination and the in-plane directions can be captured in a single measurement session.
- The oriented state and crystallinity of organic thin layers can be evaluated in a short time.

Reflection SAXS/WAXS measurement optical configuration

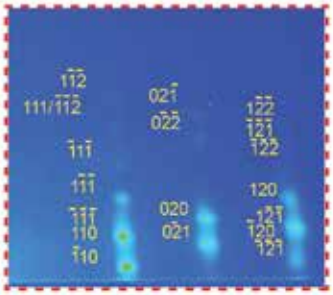


Phase identification of pentacene thin film with GI-WAXS



In-plane direction

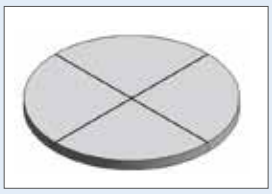
Thin-film phase

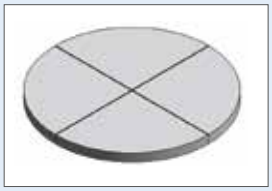


Thin-film phase is detected.

Optional attachments and sample holders

Sample plate


4” wafer sample plate


4” wafer sample plate (9 mm)


6” wafer sample plate


8” wafer sample plate


Height reference sample plate

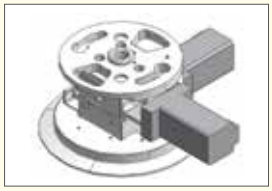

Transmission SAXS sample plate

Attachment head

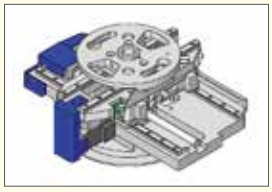

Battery cell ATT. head


Capillary spin ATT. head


Standard ATT. head


RxRy-ATT. head


XY 20 mm-ATT. head


XY 4-inch ATT. head

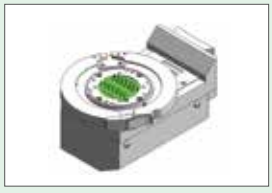
Attachment base

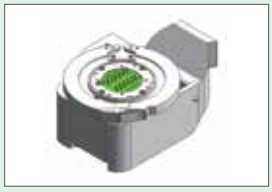

Standard ATT. base


ASC-6 ATT.

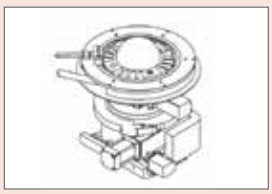

χφ ATT.


αβ ATT.

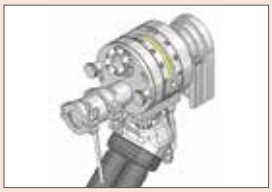

β ATT. base

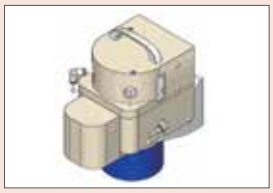

φ ATT. base

Non-ambient chambers


DHS 1100*


HTK 1200N*


TTK 600*


DSC attachment


Reactor X (infrared heating high temperature attachment)


Multipurpose high temperature attachment

*Products of Anton Paar. Many other Anton Paar attachments are available for SmartLab.

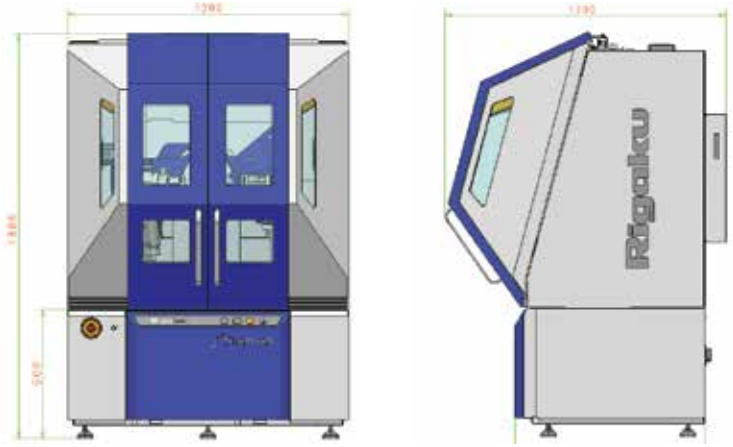
Specifications

X-ray generation*		
X-ray generator	3 kW for sealed X-ray tube	9 kW for PhotonMax rotating anode
Tube voltage variable range	20 – 60 kV	20 – 45 kV
Tube current variable range	2 – 50 mA (option 60mA)	10 – 200 mA

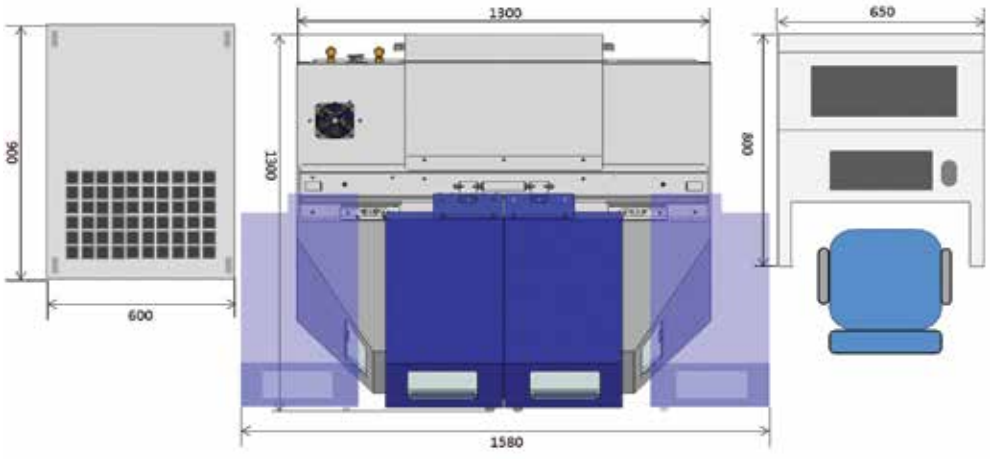
Installation requirements		
Enclosure dimensions	1,300 x 1,300 x 1,880 mm, 51.2 x 51.2 x 74.0 inch (W x D x H)	
Weight (without any options)	~750 kg, ~1,653 lb for standard configuration	~850 kg, ~1,874 lb for standard configuration
Power supply	Three phases AC200 V, 50/60 Hz, 30 A or single phase AC220 – 230 V, 50/60 Hz, 40 A	Three phases AC200 V, 50/60 Hz, 60 A
Ground resistance	≤ 100 Ω	

*The maximum rated values depend on the type of X-ray tube (target, focus). Please refer to the instruction manual of the X-ray tube for details.

Dimensions (unit: mm)



Example of installation layout



Additional technologies from Rigaku

MultiMax-9

Multipurpose rotating anode X-ray generator

MicroMax-007HF

Microfocus rotating anode X-ray generator

Confocal Mirror

Multilayer optics

RX series

Multilayer optics

MicroMax-003

Multipurpose sealed tube X-ray generator

FR-X

Ultrahigh-intensity microfocus rotating anode X-ray generator

CBO series

Cross Beam Optic units

$K\alpha_1$ optics

X-ray generators

In 1952, Rigaku was the first company in the world to commercialize a rotating anode X-ray generator. Today, Rigaku's product line ranges in output from 50 to 9000 W, and at our Yamanashi plant and US facilities we develop and produce everything from high-brightness, high-output types, to sealed tube microfocus X-ray generators. In the area of high-voltage generation power supplies, we develop and produce molded types more compact and stable than previous systems.

X-ray optics

At Rigaku Innovative Technologies, which became part of our group in 2000, we are developing and manufacturing X-ray spectroscopy and focusing components. A key part of high-precision, high-sensitivity X-ray analysis is focusing X-rays and making them monochromatic or parallel using optic elements fabricated with sophisticated technology for artificial multilayer stacked films. At our Osaka factory, we develop and manufacture analyzing crystals for wavelength dispersive X-ray fluorescence spectrometers. The CBO (Cross Beam Optics) series, which facilitates optical system switching, also broadens the possibilities of X-ray analysis.

HyPix-6000C/6000HE

Hybrid pixel array detector

HyPix-3000

Hybrid pixel array detector

HyPix-400

Hybrid pixel array detector

D/teX Ultra250/250HE

High-resolution and high-speed 1D silicon strip detector

XSPA-400ER

Seamless Multidimensional Pixel Detector

XSPA-1M

Ultra-high-speed photon counting hybrid 2D X-ray detector

XSPA-4M

Ultra-high-speed photon counting hybrid 2D X-ray detector

XSPA-500K

Ultra-high-speed photon counting hybrid 2D X-ray detector

X-ray detectors

Among Rigaku's X-ray detectors, the mainstay systems are direct-detection semiconductor detectors such as the 1-dimensional D/tex Ultra250/250HE series and 2-dimensional HyPix series, which combine high speed, low noise, high resolution and other features. Our Yamanashi factory is equipped with a cleanroom, a semiconductor process line and bonding equipment, and we produce detectors in-house. At Rigaku Innovative Technologies Europe s.r.o., established in 2008, we are also developing devices such as ultrahigh-resolution CCDs. We are continuing our detector innovation in pursuit of greater convenience, such as simple switching between 0, 1 and 2 dimensions.

TÜVRheinland CERTIFIED

Management System
ISO 9001:2015
ISO 14001:2004

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Rigaku Yamanashi Plant has obtained the international quality system certificate according to ISO 9001 and ISO 14001 and is addressing continual improvement with the PDCA cycle to provide reliable products to customers.

SmartLab

Automated multipurpose X-ray diffractometer

Scan and receive this brochure in your inbox

www.rigaku.com | info@rigaku.com

Rigaku

BR_25_SmartLab_brochure_en_4064745726