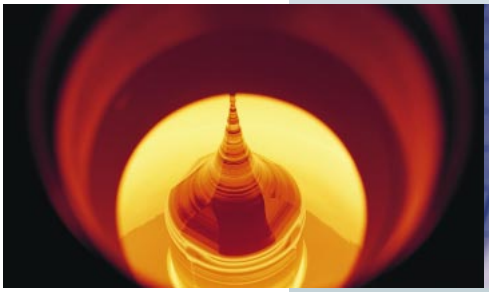
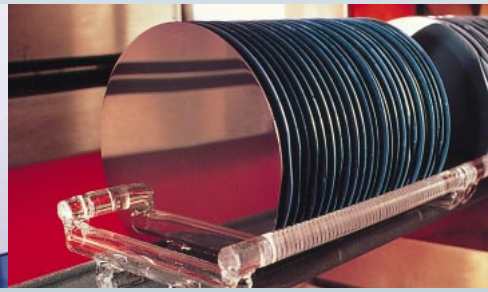
Rigaku

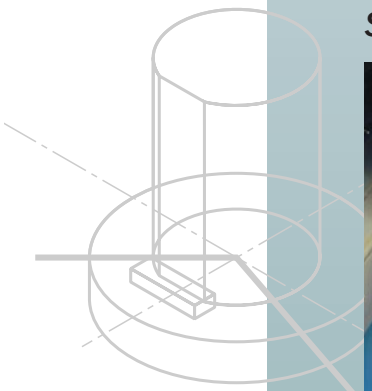
From production to quality control of single crystal materials

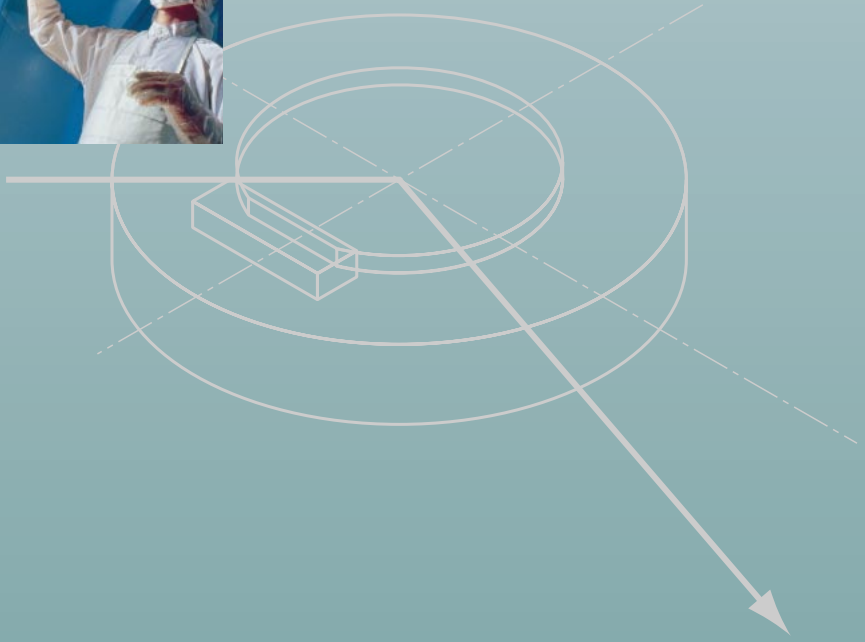
X-ray Diffraction Systems for Single Crystal Orientation and Quality Assurance





Rigaku X-ray systems help in keeping both high quality and high yield single crystal processes at their peak by providing accurate measurement systems for ingots and wafers





Broad Application Range

X-ray diffraction system for single crystal orientation measurement

2991F2/2991G2

These manual operation systems provide easy setup and operation, yet offers versatility in measurement methods to cope with various types of single crystal materials.

2991F2
(with full-enclose type radiation enclosure)

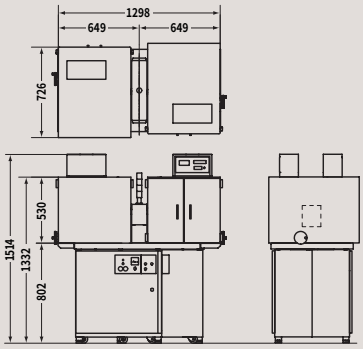
With no radiation enclosure

Sample measuring section

- Before cutting, the orientation of various types of single crystals can be determined easily. Depending upon the type and size of the single crystal (ingot or wafer), various types of the sample holders are available. (Custom made sample holder may become necessary if the sample shape, cutting angle or the design of sample holder base, which fits to the specific cutting machine is special.)
- The angular cut of an ingot block or wafer crystal can be measured easily for verification after cutting.
- A diffraction peak is found by turning a sample rotation handle located outside of the radiation enclosure. The operator can easily reads the diffraction peak position shown on the digital angle display.
- Two types of radiation enclosures are available, full enclosure with fail-safe function and a half-enclose type without a fail-safe function. Both X-ray diffraction systems, 2991F2 and 2991G2, can be operated without a radiation enclosure, however adequate radiation safety measures must be taken into account in order to comply with local regulations.

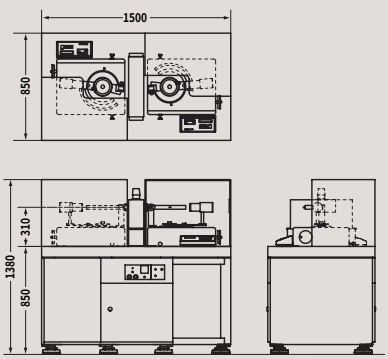
※The use of the full-enclosed type radiation enclosure is highly recommended for maximum operational safety. In the case that only the half-enclosure type or no radiation enclosure is used due to the nature of working environment and conditions, the user is urged to prepare a room dedicated to the X-ray system. Proper measures must be taken in order to comply with local X-ray safty regulations.

2991F2



2991G2
(with half style radiation enclosure)

2991G2

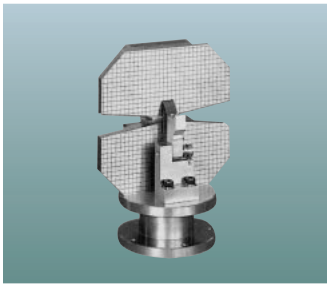


- The system is designed for heavy loads.
- 299G2 can accept heavier sample or a heavier sample holder than that by 2991F2.

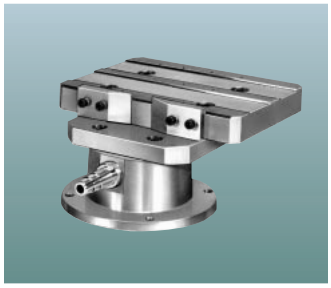
Specifications

				2991F2	2991G2
X-ray generator	X-ray tube target			Cu	
	X-ray tube cooling method			Forced air cooling with fan	
	Maximum rating			Tub voltage: 30kV fixed, Tube current: Adjustable up to 5mA	
	Main shutter			Manual opening	
X-ray detector	Detector			2-inch scintillation counter	
	Detection sensitivity			**20,000cps**	
	Time constant			0.1, 0.4sec (by selector switch)	
	X-ray intensity reading			**by meter**	
Goniometer	Measuring angle range			2**θ**=0 to 110 °, **θ**=10 to 60 °	
	Angle reading			Digital display of angle in degrees, minutes, seconds	Digital display of angle in degrees and hundredths of degrees
	Angular adjustment			Digital display is presettable at an optional reference angle with digital switches	
	Incident beam slit			0.05, 0.1, 0.2mm wide (manual slit exchange)	
	Display panel			Intensity meter, with adjustable range, Digital display of deflection angle	
	Rotary shutter			For full-enclosed type radiation enclosure (with fail-safe function): Electromagnetic rotary shutter For half-enclosed type radiation enclosure: Manual shutter interlocked with protector on the goniometer. (Protector on the goniometer can not be used if the sample size is too large.)	
Sample				Various single crystals	
Sample holder (option)	Shape & size	Wafer	Cut plane	6 in. dia. (max.) is standard. (8 in. dia. when customized — Option)	8 in. dia. (max.) is standard. (12 in. dia. when customized — Option)
			Orientation flat plane		
		Ingot	Orientation flat plane	6 in. dia. (max.)	8 in. dia. (max.)
Measurement Precision	Total accuracy			±30"	±0.01 °
External dimensions, weight				1296mm (W)×726mm (D)×1514mm (H), 300kg	1500mm (W)×850mm (D)×1380mm (H), 500kg
Radiation enclosure (for selection)				Fail-safe full-enclose type, No fail-safe half-enclose type	
Power requirement				100V AC, 15A (50/60Hz)	

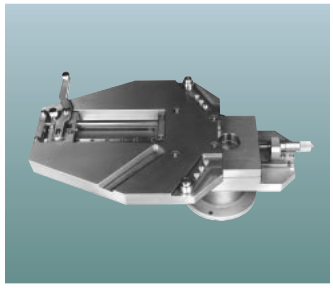
Standard Sample Holders



Spring Type Wafer Holder:
Holders for different wafer diameters are available. Wafer is secured by a spring holding system.
2991H3 for 3" dia.
2991H4 for 6" dia. 2991H5 for 8" dia.

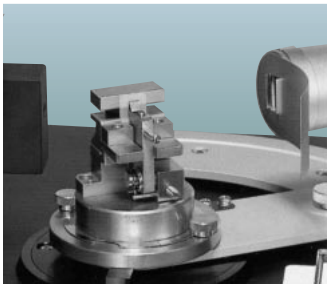


Wafer Holder for Orientation Flat Measurement:
2991L1 for 2" to 4" dia.
2991L2 for 4" to 6" dia.

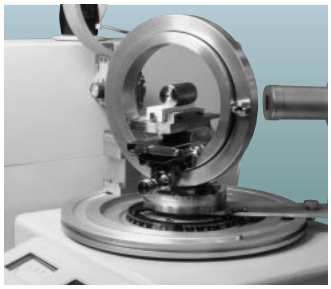


Wafer Holder for Notch or Orientation Flat Measurement:
Both the orientation flat position and notch position can be measured. Wafer is secured by a vacuum chuck system. This holder as a single unit can cope with 4" to 8" dia. wafers.

Vacuum Chuck Wafer Holder with motor-driven planar rotation mechanism for 90 ° increments.
2996A2 for 3" to 6" dia.
2996A3 for 3" to 8" dia.

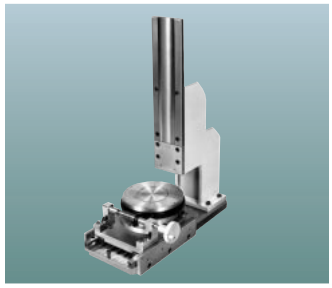


Spring Type Wafer Holder for Small Wafer:
2991H2 for small samples like a quartz chip. A thicker sample can be held as well by adjusting the spring fulcrum.



2-Axis Adjusting Ingot Jig for Determination of Cutting Orientation:
Designed to handle ingots of 10 to 30mm diameter, 10 to 100mm long. After X-Y two-axis adjustment on the jig, the adjusted ingot can be transplanted to a cutter while retaining the adjusted posture.

Ingot Jig for Crystal Axis Orientation Measurement:
Axial orientation measurement can be made with the ingot outer circumference as reference. A support stand mounted on a top plate supports the ingot weight. Designed for use with 2991G2.



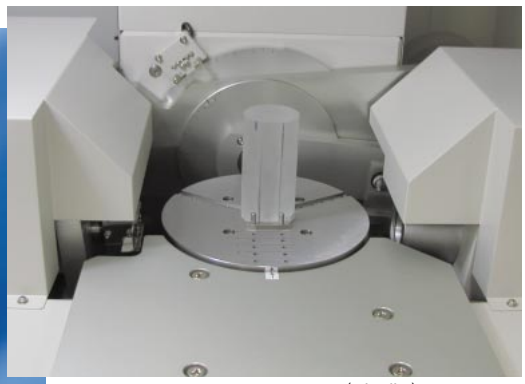
Ingot Jig for Orientation Flat Marking:
29911M1 for 3" to 5" dia.
2991M2 for 4" to 8" dia. (for 2992G2) (max. 350mm long).

Automatic Measurement of Ingot and Wafer

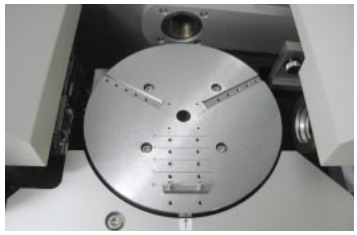
X-ray diffraction system for single crystal orientation measurement

FSAS Ⅲ

After measuring the orientation of various single crystal materials such as Si, Ge, GaAs, SiC, Quartz, LN, LT, Sapphire, Rutile and Fluorite accurately, the FSAS III transmits the angle cutting information to the cutter (for instance, to a wire saw). The orientation verification measurement of single crystals after cutting can also be carried out automatically. No special skills are required by the operator.

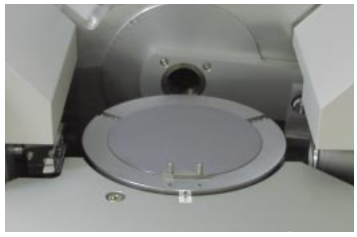


Ingot (2 in. dia.) measurement



Standard sample stage

Ingot (6 in. dia.) measurement

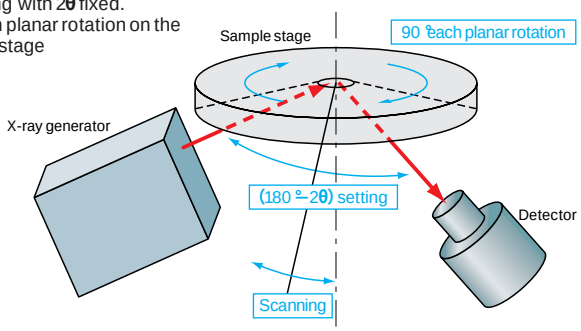


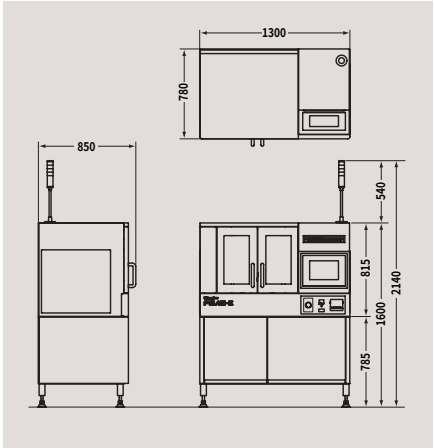
Wafer (6 in. dia.) measurement

- Even a novice can handle automatic determination of the cutting orientation of various single crystal materials. (Note; Depending on the sample shape, cutting method and cutter type, there may be a need to make a custom sample holder.)
- The cut angle of a block or wafer sample can be automatically verified after cutting.
- Once the measuring conditions are stored in the FSAS III using a touch panel interface, the operator only has to click "Measurement Start" to conduct the automatic measurement. The measurement result will then be displayed on the screen while a hard copy is being generated.
- X-ray measurement and optical system alignment are automated to ensure reliable measurements.
- Special design consideration is given to safety, so the sample insertion door will be locked instantly at the start of a measurement. Access to the sample is provided at the end of the measurement.
- The FSAS III is designed so that generated X-rays are fully confined to the system interior.

The measurement section is composed of three sections : (X-ray generator, Sample stage and Detector).

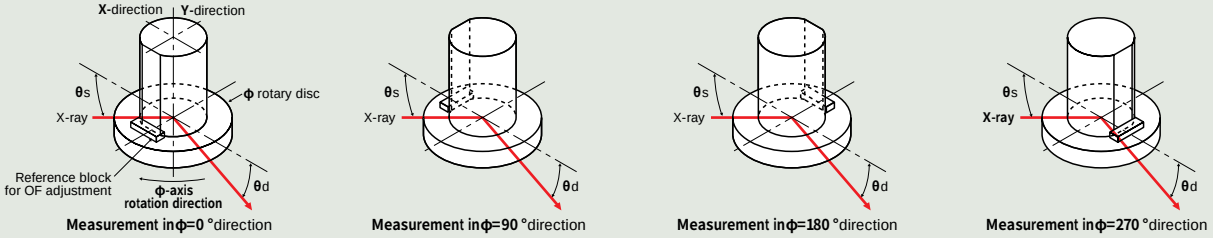
(1) (180 °-2θ) setting (Note : 2θ varies depending upon the crystal plane.)
(2) Scanning with 2θ fixed.
(3) 90 °each planar rotation on the sample stage



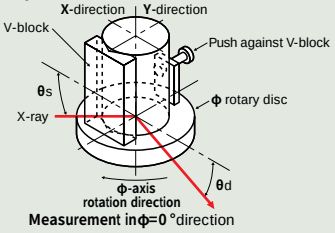


Measurement Methods for Various Sample Shapes (example)

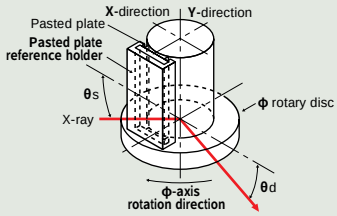
Case 1: Obtain an angular deviation of a lattice plane relative to the sample end (the sample end acts as the physical reference)
Measurement is made in four directions, **ϕ**=0 °, 90 °, 180 ° and 270 °, and, from the measurement result, the deviation angle in X and Y directions will be calculated automatically.



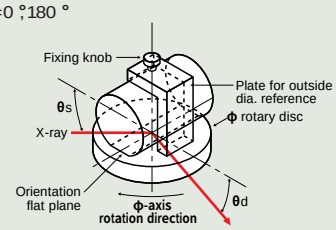
Case 2: Obtain a deviation of a crystal axis relative to the outer circumference of the sample which acts as the physical reference.
Measurement is made in four directions in the same way as above.



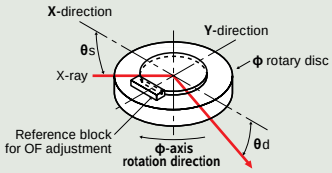
Case 3: Obtain a deviation of a crystal axis relative to a pasted plate which acts as the physical reference.
Measurement is made in four directions in the same way as above.



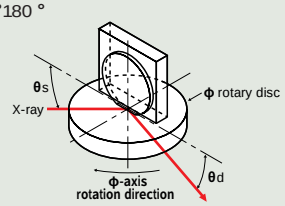
Case 4: Obtain an angular deviation on the lattice plane relative to the orientation flat (OF) of the sample. (the sample flat acts as the physical reference):
Measurement is made in two directions:
ϕ=0 °, 180 °



Case 5: Obtain an angular deviation on a lattice plane relative to a wafer (the wafer surface acts as the physical reference):
Measurement is made in four directions in the same way as above.



Case 6: Obtaining an angular deviation of a lattice plane relative to an orientation flat (OF) of a wafer (the sample flat acts as the physical reference):
Measurement is made in two directions:
ϕ=0 °, 180 °



* In addition to such absolute value measurement methods, the relative measurement mode is also selectable, in which case the deflection angle of a reference sample is read.

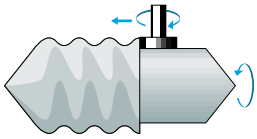
* For further details, direct your inquiry to Rigaku with such information as maximum sample size and sample weight, which affect the way of sample holding during measurement.

Specifications

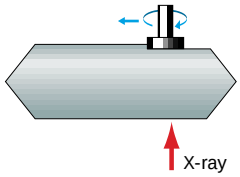
X-ray generator	X-ray tube target		Cu
	X-ray tube cooling method		Forced air cooling
	Maximum rating		Tub voltage: 30kV fixed, Tube current: Adjustable 0 to 1mA
	Control system		High frequency system
X-ray detector	Detector		2-inch scintillation counter
	Driving axis		**θ**s, **θ**d (stepping motor driving)
Goniometer	Incident angle setting (**θ**s)		0 to 50 °
	Reflection angle setting (**θ**d)		0 to 50 °
	Measuring angle range (**ω**)		±10 °
	Divergence slit		0.05mm, 0.1mm, 0.2mm by manual replacement
Sample support (sample holder exchange system)	Driving axis		**ϕ**-axis (stepping motor driving)
	Standard sample holder		Ingot axial orientation measurement with the ingot end as reference (for OF provided ingot).
			Ingot sample size: 50 to 150mm dia., 10 to 300mm long, 30kg in max. weight
			Wafer sample size: 50 to 150mm dia., 0.5 to 10mm thick (Vacuum pump for wafer fixing is available: option)
	Type		With a reference block for OF adjustment
Computer	PC		Touch panel type PC
	OS		Windows 2000
	Menu		Automatic measurement (slice plane measurement, OF measurement)
		Measurement Condition setting (Up to 5 sets are storable.)	**θ**s angle setting (Bragg angle input)
			Measurement type selection (slice plane measurement, OF measurement)
			Measurement mode selection (absolute value measurement, master comparison measurement)
			Measurement angle range designation (±10 ° in max., 0.1 ° unit) (Input of a free width is possible in absolute value measurement.)
			ω scan speed
			Alignment (system initialization, optics alignment)
Deviation angle Output	Display format		(X-direction deflection angle, Y-direction deflection angle) or (max. inclination angle **θ**, max. inclination angle **β**)
	Minimum Angle display unit		0.001 ° or 1" by choosing between decimal notation and sexagesimal notation
	Printer		Paper width: 58mm
Measurement accuracy			±30 sec. (0.012 °) (upon 5-time reproducibility test with sample fixed)
Dimensions (excluding warning lamp) & weight			1300mm (W)×780mm (D)×1600mm (H), approx. 400kg
Power requirement			100V AC, 15A (50/60Hz)

X-ray Systems Used in Working Process from Ingot to Wafer

Cylindrical grinding

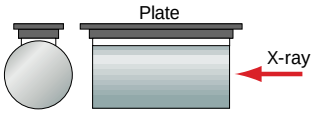


OF (or notch) working

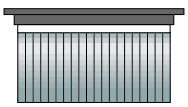


Both ends cutting

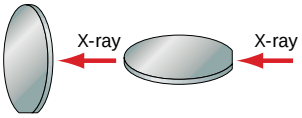
Plate pasting



Cutting into wafer



Wafer after cutting



When combined with cylindrical grinder

OF plane detection

X-ray Diffraction Measuring System GOX for Orientation Flat Detection with Cylindrical Grinder

- Detection of the OF/notch operational position is made in combination with a cylindrical grinder.
- Detection of the OF plane is made by rotating an ingot until the plane of interest is located.
  The measurement in combination with the grinder position can be used to determine the rotational position of the sample for the grind/notch operation.
- Precise OF measurements can be made after grinding, while the ingot is still chucked.

Radiation enclosure interior at time of **measurement**

Crystal axis orientation measurement

X-ray Diffraction System SAM-3 for Automatic Ingot Crystal Axis Orientation Measurement

- Automatic measurement of the inclination of the crystal axis relative to the ingot's physical axis.
- With a plate as reference, measurments are made to determine the inclination angle (deviation angle) of the crystal axis in X and Y directions.
- When the reference plate is set on the cutter, (e.g. a wire saw), the reference plate is positioned based on the previously measured deflection angles.
- Operation is made using a touch-panel.
- Since the same sample reference plate is used on the diffraction station and the cutter, a high-precision wafer cutting operation will be performed.

Attachment for OF and notch is normally installed perpendicularly to the holder.

Cut plane, OF/notch plane inspection

X-ray Diffraction System FSAS II for Automatic Wafer Crystal Plane Orientation Measurement

- The cut angle of the wafer surface plane and OF/notch position are automatically measured.
- The sample is held by a vacuum chuck.
  Automatic scanning is made for each planar rotation position at 0, 90, 180 and 270 °, and the peak position is detected at each position.
  With the wafer physical cut plane as reference, calculations and output of the deflection angle of the crystal axis are made in the X- and Y- directions.
- When a specific attachment is added, OF/notch measurement can also be carried out.
- Operation is made using a touch-panel.
- Measurement errors caused by operator can be eliminated thanks to automatic measurement and calculation.

Analysis of Crystal Quality

X-ray topographic imaging system

XRT-100/150/200/300

4" dia / 6" dia / 8" dia / 12" dia

In recent years, there has been a remarkable increase in the number of devices on various single crystal materials such as Si, Ge, GaAs, SiC, Quartz, LN, LT, Sapphire, Rutile and Fluorite.
The XRT system is specifically designed to aid in the quality control of the single crystal substrates for these new devices.

Overall view of **XRT-300 system**

Imaging plate reader **R-AXIS DS3C**

- Safe and simple operation by the joint use of a X-ray imager and computer system.
- Significant reduction in measurement time can be made when an imaging plate (IP) reader is combined with the XRT system, as compared with film techniques. Further, image processing can be performed on a local computer system.
- The wafer can be observed by the Lang method (transmission method) with a Mo target.
- Replacement with a Cu anode for the X-ray source should be made for reflection method measurments (a vacuum path is also required).
- A bend correction mechanism unique to Rigaku allows the observation of bent crystals according to their curvature.
- For the X-ray source, 3kW type (sealed tube) and 18kW type (rotating anode) are available.

Evaluation of crystal imperfection

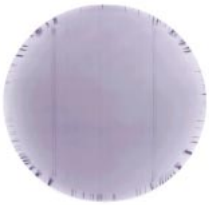
Feedback to crystal production condition

Stacking fault image

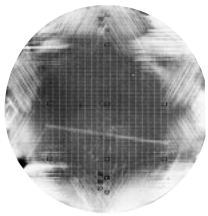
Dislocation image

Point image of precipitate

Loose striped-pattern contrast due to temperature change of impurity

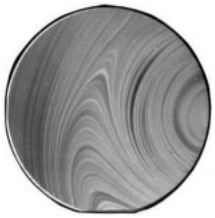


300mm Si wafer
Slips due to heat treatment can be observed.



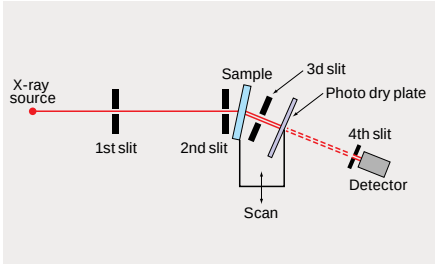
Wafer after processing
Slips due to processing can be observed.

LN wafer
Deviations in crystal plane orientation can be observed.

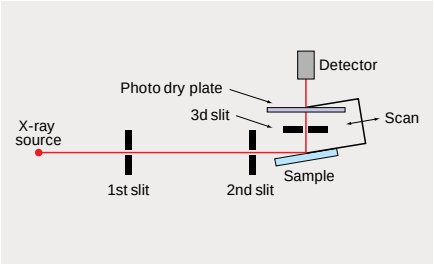


GGG wafer
Growing stripes can be observed.

Principle of transmission method



Principle of reflection method

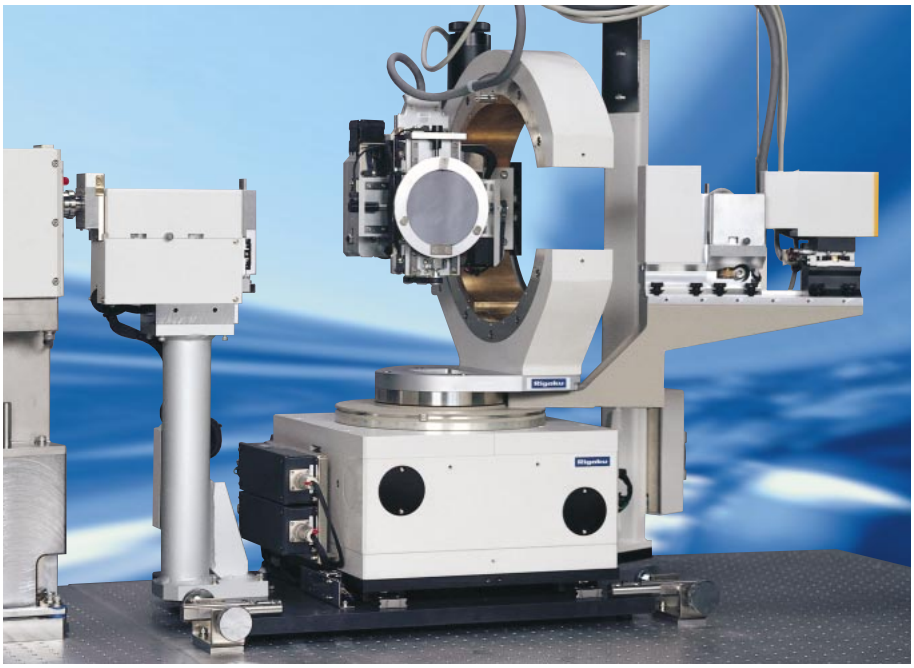


Precision Measurement of Lattice Parameters

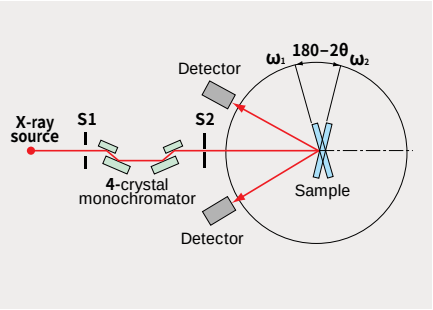
X-ray diffraction system for evaluation of single crystals

ATX-E

An approach to crystal evaluation from the viewpoint of lattice parameters.
Structure evaluation of various thin films after film deposition can be handled as well.



Bond method attachment mounted on ATX-E



Bond method optics

- Measurement by the Bond method optical system can be made:
  The ATX-E combined with a Bond method attachment (optional) permits precise measurement of lattice parameters.
  The 4-crystal channel-cut monochromator, and slit collimation can be selected safely and easily through operation from the CPU.

  Lattice parameters of a crystal are dependent on its composition, so precision measurements of those parameters makes it practical to estimate the composition.
- Rocking curve measurement:
  Evaluation of crystallinity and grain boundary can be made through FWHM and peak split.

Specifications subject to change without notice.

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