High-throughput, high-resolution X-ray topography imaging system
XRTmicron

1. Introduction

The XRTmicron is a topography measurement system which can reduce measurement time by one order of magnitude compared to previous systems by using a new high-brilliance microfocus X-ray source, together with an X-ray mirror optical system and high-sensitivity/high-resolution X-ray camera designed for that source (Fig. 1). Furthermore, it can automatically perform tasks ranging from sample setting to measurement and crystal defect analysis, and thus is useful not only for R&D but also for quality control. It can also non-destructively detect problems such as dislocations and other crystal defects, threading dislocations to the surface, and defects of the epitaxial layer. By customizing the configuration of the target, optical system, detector, sample stage and loader (automatic transfer unit), the system can be applied to a diverse range of monocrystal materials including Si, SiC[1], GaN, Ge, GaAs, quartz, LN, LT, sapphire, rutile, and fluorite. It can also handle samples in a variety of forms.

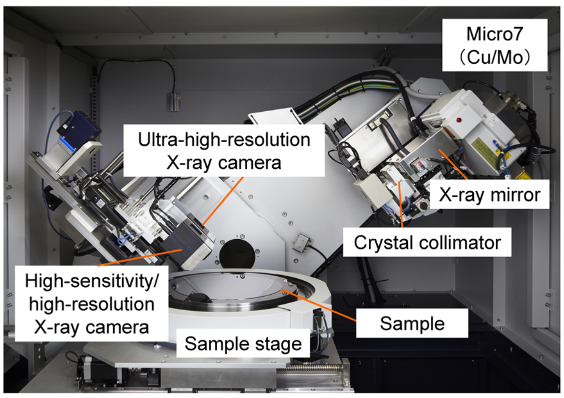

Fig. 1. Internal structure of XRTmicron.

2. Features

2.1. Use of a high-brilliance microfocus X-ray source

Higher resolution topography images are achieved by using a high-brilliance, microfocus X-ray source. Power savings havebeen acheived by reducing the rated output from 18 kW to 1.2 kW. The user can select either a dual target (Cu/Mo) equipped with an automatic target switching function for measurement with both reflection and transmission geometries, a Cu target specially for reflection geometry, or a Mo target to be used specifically for transmission geometry.

2.2. Use of X-ray mirror optical system

By using an artificial multilayer mirror with a parabolic surface, the X-rays are converted to a monochromatic, collimated beam. This makes it possible to photograph topography images of the $K\alpha_1$ component only, without using mechanical slits.

2.3. Compatible with crystal collimators

By using a 2-crystal or 4-crystal collimator (monochromator), it is possible to produce an extremely parallel X-ray beam and obtain a reflective topography image which is sensitive to lattice distortion. Switching between configurations with and without collimation is computer controlled.

2.4. Automatic switching between transmission and reflection geometries

Switching can be done automatically from the computer between the transmission geometry for observing inside a crystal (Mo), and the reflection geometry for observing near the surface (Cu) (Fig. 2).

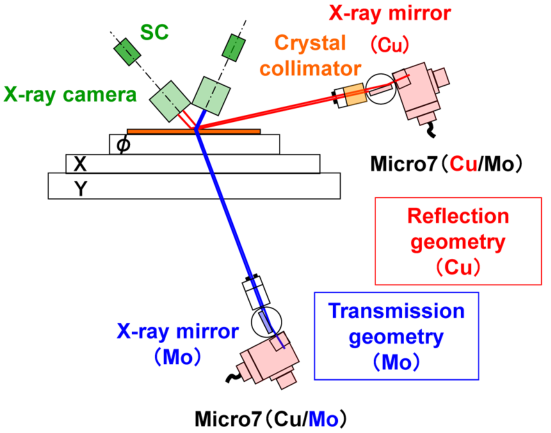

Fig. 2. Conceptual diagram of XRTmicron.

2.5. Automation of measurement

The flow of a sequence of operation can be visualized using the flow bar display, and this enables smooth execution of measurement operation. The system also supports automatic measurement using batch processing (Fig. 3).

2.6. High-sensitivity, high-resolution X-ray camera

Digital images can be captured with a high-sensitivity/high-resolution X-ray camera (pixel size 5.4 μm, image size 18 mm × 13.5 mm (3,326 pixels × 2,504 pixels)) (Fig. 4). The system can also be switched to use an ultra-high-resolution X-ray camera with a pixel size of 2.4 μm.

2.7. Section topography

It is also possible to capture section topography images, which include position information in the depth (thickness) direction on lattice defects in the sample.

2.8. Various wafer sizes can be handled

The XRTmicron can handle wafer sizes of 3, 4, 6, 8 and 12 inches. It can also handle 450-mm wafers.

2.9. Loader (automatic transfer unit)

It can automatically transfer 3, 4, 6, 8 and 12-inch wafers with an optional loader.

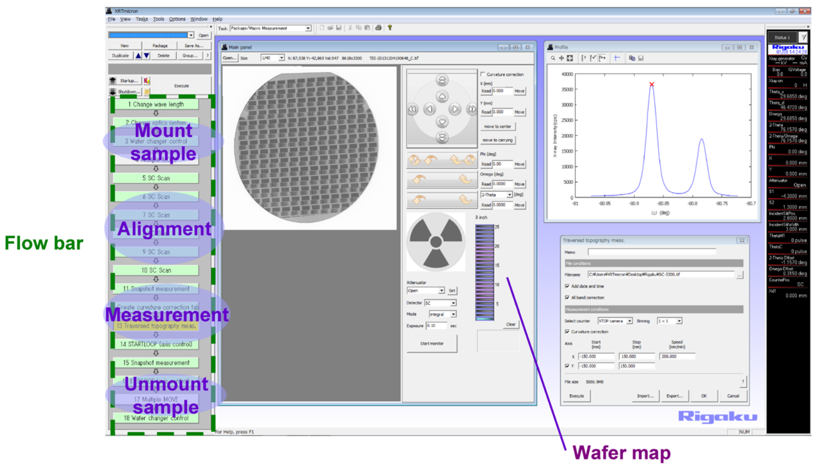

Fig. 3. Sample screen of measurement software.

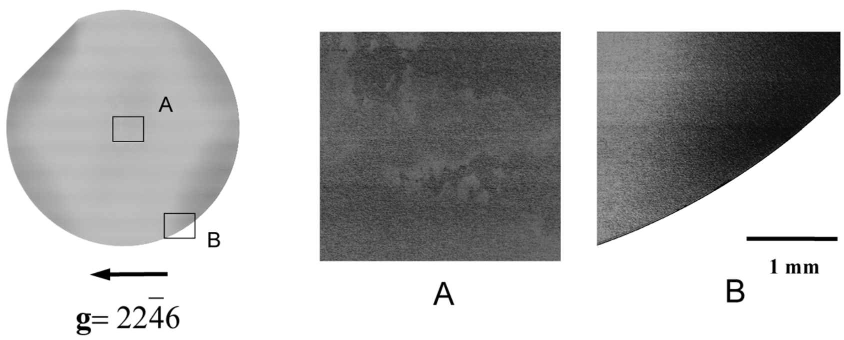

Fig. 4. Reflection topography image of 6-inch r-plane sapphire substrate. Differences in defect density appear as shades of gray.

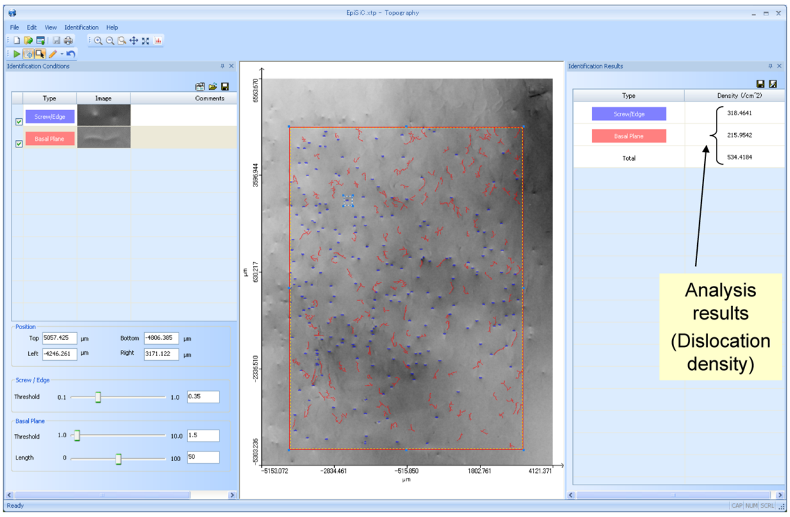

Fig. 5. Software for automatic analysis of dislocations.

Table 1. Specifications.

Dimensions and weight	Main unit 1,800 mm (W)×1,870 mm (D)×1,980 mm (H), 2,200 kg (without loader) Main unit 1,800 mm (W)×1,800 mm (D)×1,980 mm (H), 2,200 kg (with loader) Loader 1,490 mm (W)×1,350 mm (D)×1,700 mm (H), 360 kg
Power supply	Equipment main unit 3ϕ 200 V 15 A 5.2 kVA (without loader) Equipment main unit 3ϕ 200 V 16 A 5.6 kVA (with loader) Circulating water supply unit 3ϕ 200 V 12 A 4.1 kVA Computer 1ϕ 100 V 8A 1 kVA
X-ray source	High-brilliance micro-focus X-ray source RA-Micro 7HFMR Max. rated output: 1.2 kW (Cu 40 kV-30 mA, Mo 50 kV-24 mA) Focus size: Cu ϕ 0.07 mm, Mo 0.15×0.10 mm²
Goniometer section	θ–θ type sample horizontal high-precision goniometer θs single −95° to +50° (reflection/transmission geometry measurement) θs single −5° to +50° (reflection geometry measurement) θd single +30° to +130°

(Specifications may be changed due to the equipment configuration.)

2.10. Automated curvature correction mechanism

Topography images can be taken even of curved crystals by compensating for the degree of curvature. Preparation of tables for curvature collection has been automated.

2.11. Crystal defect analysis using topography analysis

For a number of monocrystalline materials, software has been developed to enable identification of islocations and measurement of dislocation density (Fig. 5). In the future, we plan to steadily increase the types of crystals and defects that can be analyzed.

References

(1) K. Omote: *Rigaku Journal (English version)*, **29** (2013), No. 1, 1–8.