BL16B2
RIKEN Analytical Science II

1. Introduction

BL16B2 was transferred from a contract beamline (SUNBEAM BM) to a RIKEN beamline (RIKEN Analytical Science II) in FY2024. The beamline is utilizing a bending magnet source, capable of providing an X-ray beam with a maximum horizontal width of approximately 50 mm for experiments. The beamline consists of an optics hutch (OH) and an experimental hutch (EH). The optics hutch contains a double-crystal monochromator (DCM), slits (Transport channel slits (TCSs) 1–3), and a mirror, while the experimental hutch was equipped with a large experimental table and a 6-axis diffractometer. The basic specifications of the beamline and a diagram of the equipment layout are shown in Table 1 and Fig. 1, respectively.

In FY2024, the 6-axis diffractometer was upgraded to an X-ray topography system equipped with a wide-field, high-definition digital camera and will be available for public use.

Table 1. Basic specifications of BL16B2.

Light source	Bending magnet
Energy range	7–37 keV (Si111)
Photon flux	$\sim 10^{10}$ photons/s
Maximum beam size	50 mm (H) × 5 mm (V)
Experimental station	High-throughput X-ray topography system

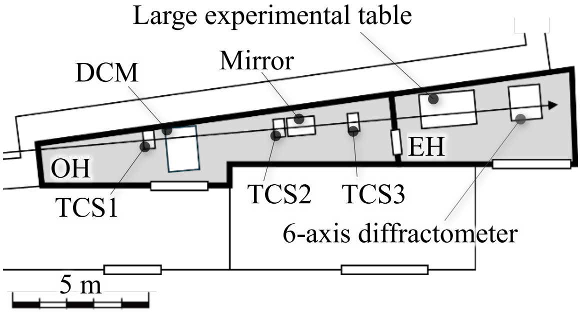

Fig. 1. Layout of BL16B2.

2. Development of High-Throughput X-ray Topography System

X-ray topography is an imaging technique that, combined X-ray diffraction, can nondestructively visualize the spatial distribution of lattice defects of a single crystal. It is often used for evaluating semiconductor materials. In recent years, it has been applied to wide-bandgap semiconductors such as SiC, GaN, and diamond wafers to determine the density, spatial distribution, and types of dislocations. The diameter of wafers, which serve as substrates for semiconductor devices, is tending to increase year by year to produce a larger number of integrated circuit chips from a single wafer. Therefore, X-ray topography requires a wide field of view to accommodate large-diameter wafers and a high spatial resolution to observe dislocations of a few micrometers. Currently, X-ray films and nuclear emulsions, which relatively easily meet these requirements, are often used as detectors. However, the preparation and development of X-ray films and nuclear emulsions are time-consuming and labor-intensive, which can reduce measurement efficiency. To solve these problems, we developed a high-throughput X-ray topography system equipped with digital cameras and introduced it to BL16B2. Figure 2 shows an external view of the system. One of its key features is that it is equipped with two DIFRAS detectors [1]: a high-resolution (HR) type and a large-field-of-view (LFOV) type.

The HR-type detector has a pixel size of 0.72 µm and a field of view of 10 mm × 7.7 mm, while the LFOV one has a pixel size of 3.8 µm and a field of view of 53 mm × 40 mm. Since both types have a large number of pixels (14,192 × 10,640), they achieve a balance between resolution and field of view.

Another feature is a large stroke of the sample stage, which can move ±100 mm within the sample plane. For samples larger than the detector's field of view, we combine the use of this stage with scanning. In reflection-geometry X-ray topography, one can observe wafers of up to 8 inches without manual repositioning. The center of the sample stage has a 180-mm-diameter hole, which allows for the transmission-geometry observation of wafers of up to 6 inches.

Figure 3 shows an X-ray topograph image of SiC measured with the high-resolution detector of this system. In the magnified view, multiple types of dislocation images were clearly observed, which means that an image quality equal to or better than that of a nuclear emulsion plate was obtained without the need for development process.

The exposure time for a single image with this system is a few seconds to a few minutes, depending on the sample's condition. While the measurement time increases with the sample's area and does not always shorten the total time compared with X-ray film, this system has the potential for reduced measurement times after the optimization of several experimental parameters. Regarding convenience, our system has a significant advantage over X-ray films because it eliminates the need for preparation and development. Other advantages of this system include its ability to provide quantitative intensity comparisons and its wide dynamic range, which makes it easily applicable to advanced observation methods such as rocking curve imaging and step-scan section topography.

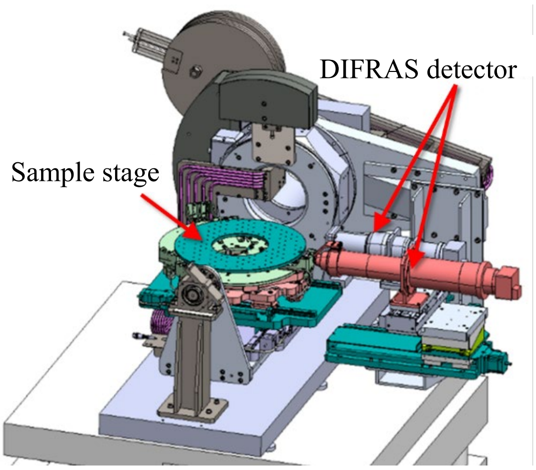

Fig. 2. High-throughput X-ray topography system.

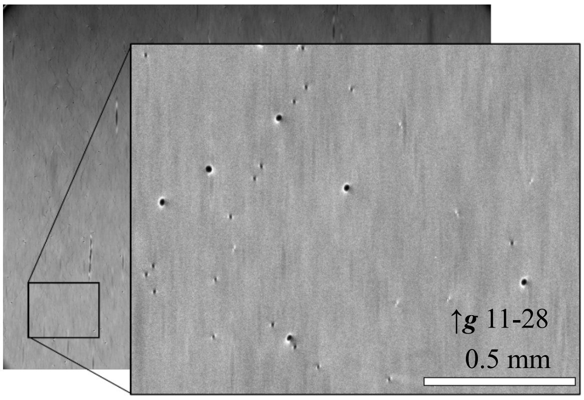

Fig. 3. X-ray topographic image of SiC. Full-field and magnified images from the high-resolution detector. 11-28 diffraction, X-ray energy of 8.5 keV, and exposure time of 10 s.

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References:

[1] Kameshima, T. & Hatsui, T. (2022). *J. Phys.*: *Conf. Ser*. **2380**, 012094.