BL24XU
Hyogo ID

1. Introduction

BL24XU is known as the Hyogo ID beamline. It is a contract beamline designed by Hyogo Prefecture for industrial applications. BL24XU is a branched beamline employing a figure-8 undulator light source, a diamond (220) beam-splitting monochromator for branched line A, and a Si (111) double-crystal monochromator (DCM) for mainstream B. The end-station is specialized for high-resolution structural characterization using microbeams and imaging (Table 1).

Recently, we have begun actively promoting the use of data-driven science and engineering, such as applying machine learning to analysis utilizing synchrotron radiation. The informatics approach has the potential to rapidly derive the relationships among the structure, physical properties, and manufacturing processes by analyzing a number of specimens under different conditions. In addition, it may extract useful features from massive amounts of data, such as two-dimensional spectrum mappings.

Efforts continue in the development of new measurement methods. Bright-field X-ray topography, which was developed in recent years, is now available to industrial users. Here, we report its developments.

Table 1. Specifications of the measurement techniques in BL24XU.

Measurement technique	Structural information	Spatial resolution
Projection/imaging microscope/coherent diffraction CT	2D/3D image Field of view: 1 μm–1 mm Absorption, refraction contrast (projection/imaging microscope) Absorption, phase contrast (coherent diffraction)	10 nm–0.33 μm
Microbeam SAXS/WAXD/ XRF	Periodic/aggregation structures from angstrom scale to several hundred nm in size Distribution of crystal grains Elemental mapping	0.5–5 μm
Bonse–Hart USAXS	Periodic/aggregation structures 16 nm–6.5 μm in size	Bulk
Highly parallel microfocus diffraction, bright-field topography	Local strain, dislocation	0.5–30 μm (diffraction), 0.65 μm (topography)
Near-ambient-pressure HAXPES	Chemical state	30 μm

2. Reflection Topography

At BL24XU, we previously observed dislocations within semiconductor crystals by transmitted topography in bright-field illumination [1]. In FY2024, we attempted to apply X-ray reflection topography. Transmitted topography allows the observation of dislocations inside the crystal, whereas reflection topography is characterized by its ability to observe only near the surface of the crystal. In this study, we first observed dislocations

in GaN crystal substrates by reflection topography, then compared these images with those obtained via transmitted topography. The crystals observed in this experiment were GaN crystals grown by the multipoint seed method.

An X-ray beam from synchrotron radiation was set to an energy of 9.0 keV and incident on the sample, forming an optical system that captured the diffracted light with a CMOS camera. Subsequently, the diffracted light was confirmed with a fluorescent sheet, and simultaneously, an optical system was formed to capture transmitted light with a CMOS camera.

Figures 1 and 2 show the images obtained by the transmitted and reflection topography techniques, respectively. In Fig. 1, the black spots are likely to be triple points of crystal growth via the multipoint seed method, where multiple basal plane dislocations have occurred. Additionally, the black lines with start and end points inside the crystal image represent threading dislocations. Comparing with Fig. 2, the triple points appear as large cavities, while threading dislocations appear as small cavities. This suggests that the size of the cavities can be used to classify whether a dislocation is a basal plane dislocation or a through dislocation.

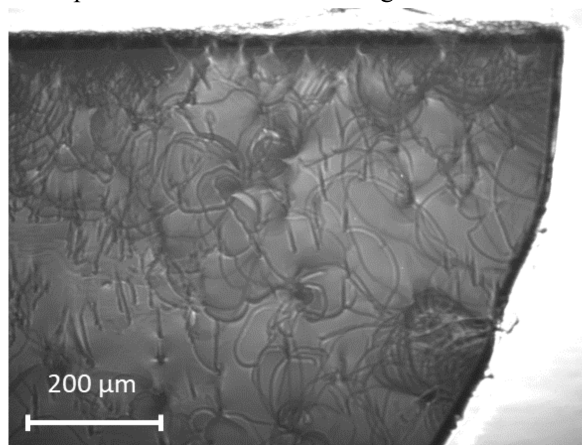

Fig. 1. Transmitted topographic image of GaN crystal grown by the Na-flux method on a sapphire substrate.

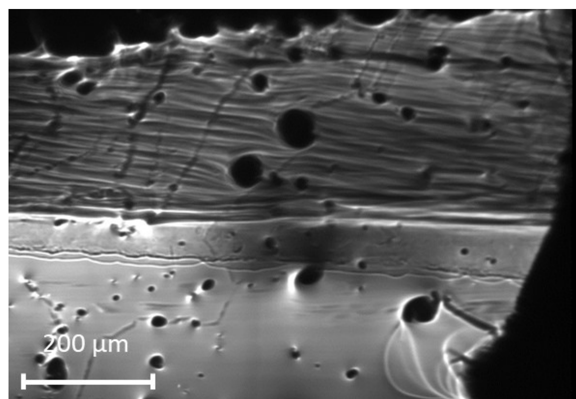

Fig. 2. Reflection topographic image of GaN crystal.

Regarding the operation of the experimental stations for user access, we would like to express our gratitude for the cooperation of JASRI.

TSUSAKA Yoshiyuki, SAWADA Takuma, KUSUMOTO Daichi, and YANAGIDA Taiki

Graduate School of Science, University of Hyogo

References:

[1] Tsusaka, Y. Takeda, S. Takano, H. Yokoyama, K. Kagoshima, Y. & Matsui, J. (2016). *Rev. Sci. Instrum.* **87**, 023701.