# 九州シンクロトロン光研究センター
# 県有ビームライン利用報告書

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（様式第５号）

## High-resolution x-ray diffraction on the homo-epitaxial GaN thin films

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### １．概要（注：結論を含めて下さい）

We have investigated the dislocation density and strain in a free-standing GaN substrate through a high-resolution x-ray diffraction technique. By observing the x-ray diffraction peak profiles of various crystal planes, we obtained the rocking curve width as a function of diffraction angle. The rocking curves obtained under the x-ray of 1 Å showed a linear increase with respect to the 2-theta angles. Due to the change of the rocking curve width, we could not evaluate the dislocation density properly. We are still finding a model suitable for the evaluation of the dislocation density with the rocking curve width.

### ２．背景と目的

The big obstacle in the mass production of GaN substrate is a high dislocation density during the GaN growth. The high dislocation density in the GaN deteriorates the LED device's efficiency and affects the high-frequency properties. Therefore, minimizing the dislocation density is a key to improve the device performance. Among the growth methods, HVPE (hydride vapour-phase epitaxy) is a promising method for the GaN growth with low dislocation density. In this research, we will evaluate the dislocation density through the x-ray rocking curve method to improve the GaN substrate quality.

### ３．実験内容（試料、実験方法、解析方法の説明）

X-rays of 1Å were selected by a Si (111) double crystal monochromator. The x-ray beam size was adjusted to be about 0.2mm × 0.2mm. A free-standing GaN substrate was mounted on the goniometer with a chi-circle for precise alignment. X-ray rocking curves of (0002), (0004), (01-14), (01-15), (02-25), (02-26), (11-24), (12-35), and high order planes were observed with a 0.001-degree step for the purpose of the effect of dislocation.

### ４．実験結果と考察

The FWHMs as a function of 2θ are described in Fig. 1. The rocking curve widths were proportional to 2θ, which cannot be explained by the relation between dislocation density and rocking curve width. According to a commonly used dislocation density formulas given by Dunn and Koch are as follows:

$$\rho_e = \frac{\Delta\omega_e^2}{4.35b_e^2}, \quad \rho_s = \frac{\Delta\omega_s^2}{4.35b_s^2},$$

Where, $\rho_e$, $\rho_s$, $\Delta w_e$, $\Delta w_s$, $b_e$, $b_s$ are edge dislocation density, screw dislocation density, FWHM of a crystal plane sensitive to the edge dislocation, FWHM of a crystal plane sensitive to the screw dislocation, Burgers vector of edge dislocation and Burger vector of screw dislocation. Because the dislocation density and Burgers vector is constant in the sample, the width should be a constant. However, according to our experiment, the width tended to increase as the diffraction angle increase. Therefore, the current dislocation density evaluation model needs to be improved.

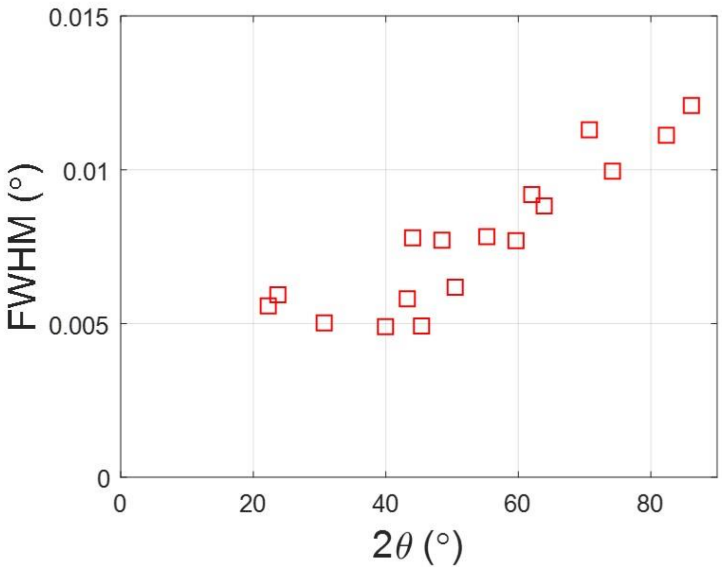


Figure 1. X-ray rocking curve width as a function of 2θ. The FWMs were increased as a function of 2θ.

## ５．今後の課題

We need to find a better model for dislocation density evaluation with an x-ray rocking curve method. A theoretical approach is essential to figure out this problem.

## ６．参考文献

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## ７．論文発表・特許（注：本課題に関連するこれまでの代表的な成果）

1. J. Kim, O. Seo, S. Hiroi, Y. Irokawa, T. Nabatame, Y. Koide, and O. Sakata, Surface morphology smoothing of a 2 inch-diameter GaN homoepitaxial layer observed by X-ray diffraction topography, *RSC Adv.* **10**, 1878-1882 (2020)
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８．キーワード（注：試料及び実験方法を特定する用語を２～３）

- ✓ GaN, wide bandgap semiconductor, dislocation density, x-ray rocking curve

９．研究成果公開について（注：※２に記載した研究成果の公開について①と②のうち該当しない方を消してください。また、論文（査読付）発表と研究センターへの報告、または研究成果公報への原稿提出時期を記入してください（2018 年度実施課題は 2020 年度末が期限となります)。
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① 論文（査読付）発表の報告 **（報告時期：2021 年 3 月）**

~~② 研究成果公報の原稿提出 （提出時期： 年 月）~~