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

課題番号： 2001133S | ＢＬ番号：BL15

（様式第５号）

X-ray diffraction topography on the homo-epitaxial GaN thin films

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※１　先端創生利用（長期タイプ）課題は、実施課題名の末尾に期を表す（Ⅰ）、（Ⅱ）、（Ⅲ）を追記してください。
※２　利用情報の公開が必要な課題は、本利用報告書とは別に利用年度終了後２年以内に研究成果公開｛論文（査読付）の発表又は研究センターの研究成果公報で公表｝が必要です（トライアル利用を除く）。
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※４　共著者には実験参加者をご記載ください（各実験参加機関より１人以上）。

１．概要（注：結論を含めて下さい）

We have performed x-ray diffraction topography imaging on the various free-standing GaN homo-epitaxial layers. X-rays of 1.284Å were selected by a double crystal monochromator. The x-ray beam size was adjusted to be the maximum for the large area illumination. In the case of m-plane GaN wafers, stripe patterns along the [0001] direction were observed. In order to understand the origin of the stripe pattern, rocking curve imaging at (10-10), (12-30) and (22-41) planes were measured. For c-plane GaN, various crystal planes – (0002), (0004), (01-14), (01-15), (02-25), (02-26), (11-24), (12-35) – were selected by calculating diffraction angles and inter-planar angles. Dislocation types were confirmed by comparing various images.

２．背景と目的

A GaN one of the prominent materials for LED (light-emitting diode), high-power device, and high-frequency devices has attracted its great attention. However, it was a big challenge to fabricate large-area GaN thin film of high crystallinity. Especially high dislocation density was a big obstacle. In order to minimize the dislocation density, many fabrication methods were proposed for the crystal quality improvement, such as HVPE (hydride vapor phase epitaxy). Although the crystal quality has been improved much, the crystal quality of large-area is not so high and homogeneous enough to mass production. Therefore, it is imperative to evaluate the whole GaN wafer qualitatively and statistically.

３．実験内容（試料、実験方法、解析方法の説明）

The x-ray diffraction topography experiment was performed at BL15, SAGA, Japan. X-rays of 1.284Å were selected by Si (111) double crystal monochromator (DCM). The x-ray bean size was adjusted to be about 5 cm × 1 cm. GaN wafers were placed in the rotation center of a goniometer. A flat panel detector of a pixel size of 50 × 50 μm^2 were placed at various Bragg angles. The diffraction images were automatically recorded with a 0.001^{o} step of the sample rotation angle. The schematic view of the experimental condition is sketched in Figure 1. The obtained images were stacked along the θ (sample rotation angle) direction and merged. Maximum intensity, peak position, and FWHM (full width at half maximum) of each detector pixel were calculated for the evaluation of the crystallinity. Similar measurements were performed on various Miller indices such as (0002), (0004), (01-14), (01-15), (02-25), (02-26), (11-24), and (12-35) for understanding of dislocation feature.

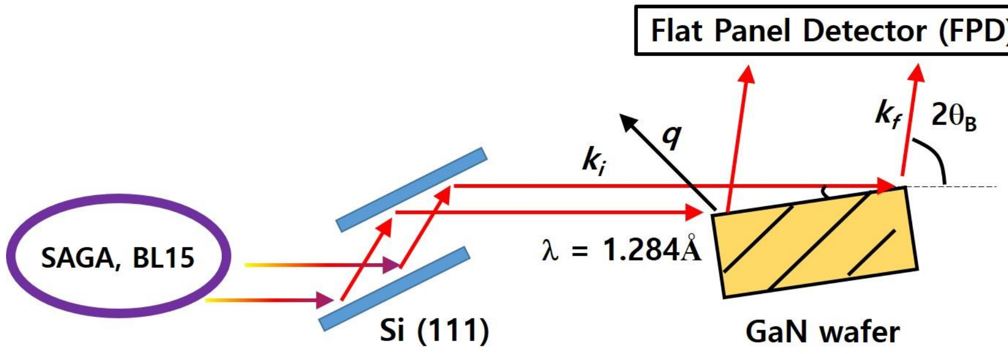

Figure 1. Schematic view of the experimental configuration. X-rays of 1.284Å were selected by Si (111) double crystal monochromator. GaN wafers were put in the rotation center. A flat panel detector was placed at Bragg angles, and diffraction images were recorded at various incident angles.

４．実験結果と考察

The merged x-ray diffraction topography images on c-plane GaN are illustrated in Figure 2. Maximum intensity, peak position variation, and FWHM map shows texture structure in the GaN homo-epitaxial layer. In the case of a (10-15) plane, the top and bottom of the image were deformed by x-ray beam size limitation. The change in images by g-vector indicates that the dislocation is dependent on the kinds of dislocation. We are analyzing the relation between g-vector and dislocation.

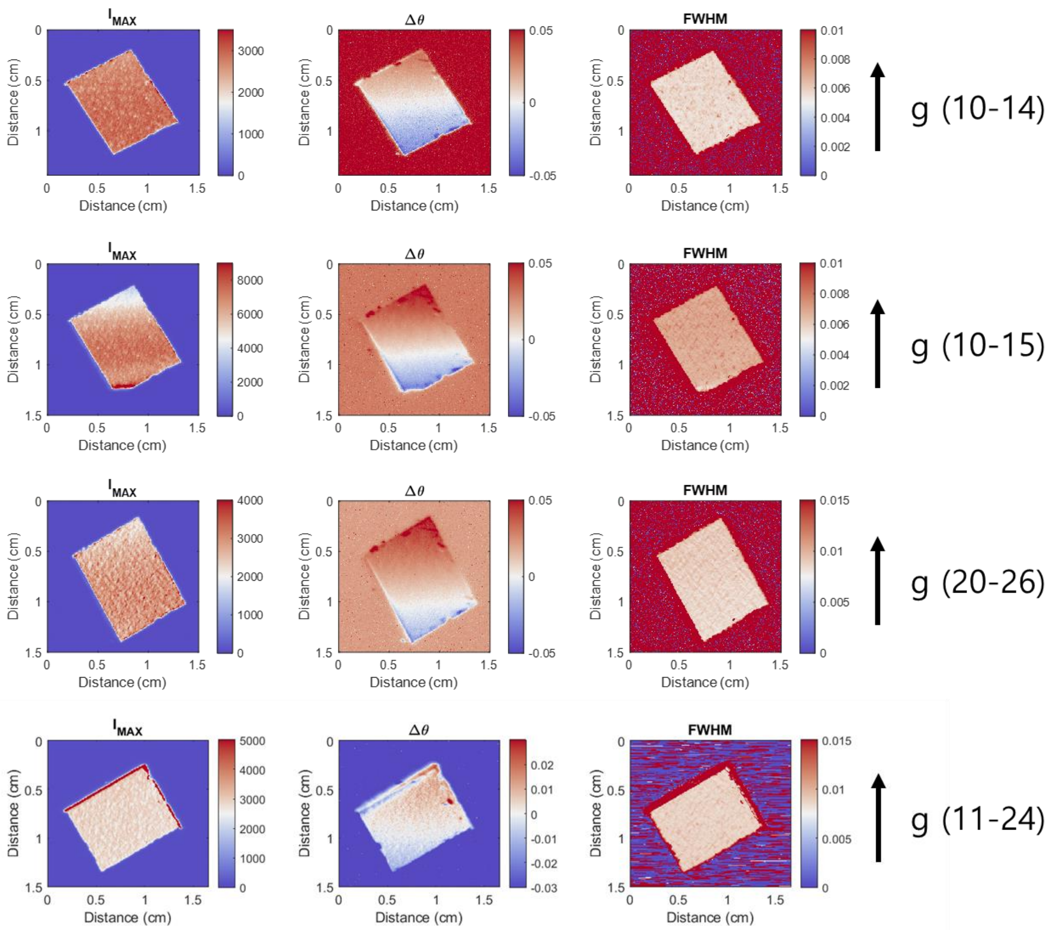

Figure 2. Merged x-ray diffraction topography images of c-plane GaN under different g-vector. The maximum intensity, peak position, and FWHM of each pixel are strongly dependent on the g-vector. The unit in peak position image is degree.

５．今後の課題

It is necessary to analyze the topography image qualitatively and statistically for the GaN wafer quality evaluation, such as dislocation density mapping.

６．参考文献

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2. J. Kim, O. Seo, C. Song, S. Hiroi, Y. Chen, Y. Irokawa, T. Nabatame, Y. Koide, and O. Sakata, Mapping of a Lattice-Plane Tilting in a GaN Wafer Using Energy-Resolved X-Ray Diffraction Topography, *Phys. Rev. Appl.* **11**, 024072 (2019)
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6. J. Kim, O. Seo, C. Song, S. Hiroi, Y. Chen, Y. Irokawa, T. Nabatame, Y. Koide, O. Sakata, Lattice-plane orientation mapping of homo-epitaxial GaN (0001) thin films via grazing-incidence X-ray diffraction topography in 2-in. wafer, *Appl. Phys. Express* **11**, 081002 (2018)
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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）

- ✓ X-ray diffraction topography, GaN, wide bandgap semiconductor

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）。

長期タイプ課題は、ご利用の最終期の利用報告書にご記入ください。

①　論文（査読付）発表の報告　　　　（報告時期：予定 **2021** 年 **3** 月）

~~②　研究成果公報の原稿提出　　　　（提出時期：　　　　年　　月）~~