Structural Analysis of Na-flux GaN by Nanobeam X-ray Diffraction: Local Lattice Constant Variation Depending on the Growth Mode

Grad. Sch. Eng. Sci., Osaka Univ.[1], Grad. Sch. Eng., Osaka Univ.[2], JASRI[3]
Z. D. Wu[1], K. Shida[1], T. Hamachi[1], Y. Hayashi [1], T. Tohei [1], M. Imanishi[2], Y. Mori[2],
K. Sumitani[3], Y. Imai[3], S. Kimura[3], and A. Sakai[1]
E-mail: sakai@ee.es.osaka-u.ac.jp

[Introduction] GaN is becoming one of the most important semiconductor materials in modern society, which is widely used in light-emitting diodes, power devices and so on. These requirements are suffering from the quality of GaN substrates. However, the Na-Flux method utilizing the multi-point seed technique (MPST) and the flux film coated technique (FFCT) has successfully prepared bulk GaN substrates with extremely high quality [1]. For further application and potential performance evaluation, it is necessary to clarify detailed structural characteristics of the substrates. In this research, we focus on bulk GaN grown with MPST combined with FFCT. Taking advantage of nanobeam X-ray diffraction (nanoXRD), as well as other analytical techniques, local lattice constant distribution is quantitatively analyzed.

[Experiment] A bulk GaN substrate with a thickness of ~1 mm and a dislocation density of ~10^5 cm^{-2} was used. First, with the help of cathode luminescence (CL) imaging in cross-sectional view of the sample, an X-ray irradiation region of 400 × 200 μm^2 for nanoXRD was decided, which is marked by the red rectangles in Figs. 1(a) and (b). NanoXRD was done in SPring-8 BL13XU with a beam size around 650 (hor.) × 410 (ver.) nm^2. There were 41 × 21 irradiation spots with an interval of 10 μm. By using Gaussian fitting for obtained diffraction profiles, details of lattice constant (2θ), lattice twisting (ϕ) and lattice tilting (ω) (Figs. 1(c)) were extracted from $2\bar{2}00$ and $2\bar{2}02$ diffractions. The multi-photon-excited photoluminescence (MPPL) observation was also utilized to image detail facet distribution in the sample.

[Results and discussion] By MPPL analysis on 3-D structure over the whole sample, the growth sectors, related to growth modes occurring in the present growth method, can be described into 4 different regions as shown in Fig. 1(b). It is also found that lattice constant ratio *c*/*a* distribution and *c*-*a* scatter plots clearly depend on the growth sectors 1 to 4 (Figs. 2(a) and (b), respectively). Since impurities, especially oxygen, are generally responsible for changing lattice constant in GaN, these results indicate the relationship between lattice constants, impurity (oxygen) concentration and the growth mode, and also inspire us the intrinsic structural boundaries within the sample.

[Acknowledgment] This work was partially supported by JST ALCA (JPMJAL1201) and JSPS KAKENHI (JP16H06423).

[References] 1. Y. Mori *et al*., JJAP 58, SC0803 (2019).

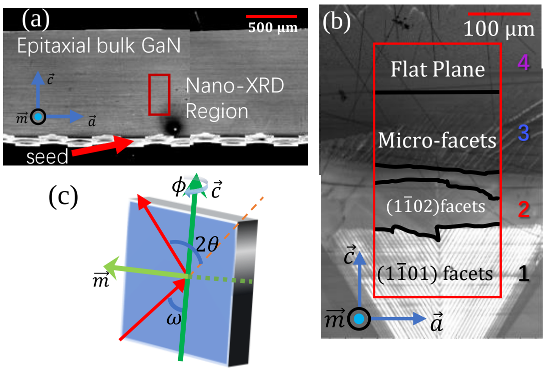

Fig. 1 (a) Cross-sectional SEM image of a part of the sample. (b) Irradiation region overlapped on the CL image. Red rectangles in (a) and (b) are the same area. (c) Schematic of diffraction geometry in nanoXRD.

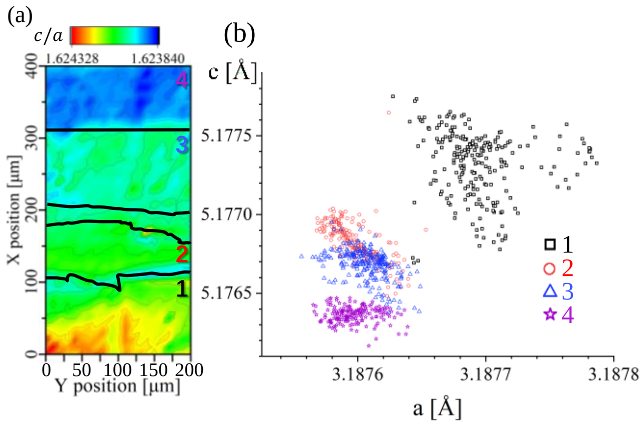

Fig. 2 Lattice constant distribution: (a) *c*/*a* distribution over irradiation region and (b) *c*-*a* scatter plots based on different growth sector shown in (a) and Fig.1(b).