Analysis of Stress and Impurity Evolution Related to Growth Sector in Na-flux GaN by Nanobeam X-ray Diffraction

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[Introduction] Due to the ideal performance and unique characteristics in the field of power devices and light emission diodes, a high quality GaN substrate is strongly required. Recently, the Na-Flux method utilizing the multi-point seed technique (MPST) and the flux film coated technique (FFCT) has successfully produced *c*-plane bulk GaN substrates with remarkably high quality[1], e.g., low dislocation density ($< 10^5$ cm^{-2}) and large curvature radius (> 30 m). The obtained crystal shows rather complex microstructure around the coalescence region (Fig. 1(a)) and detail investigation is necessary to understand the crystal and defect formation mechanisms. This research tries to reveal the structure evolution and related oxygen and stress evolution in the coalescence regions by nanobeam X-ray diffraction (nanoXRD) analysis.

[Experiment] We firstly determined an analyzed region of 400×200 μm^2 which contains the coalescence area, shown in the cross-sectional cathode luminescence (CL) image [Fig. 1(a)]. NanoXRD measurements were done in SPring-8 BL13XU with a beam size around 650 (hor.)×410 (ver.) nm^2. Lattice constants were extracted from (2-200) and (2-202) diffractions of 41×21 irradiation spots with an interval of 10 μm by using reciprocal space maps. Multi-photon-excited photoluminescence (MPPL) is also employed to image facet structure distribution. To compare with nanoXRD results, precise oxygen concentration was measured by secondary ion mass spectrometry (SIMS) at point 1 to 5 shown in Fig. 1(a).

[Results and discussion] From the MPPL analysis, the crystal near the coalescence region was classified into 4 regions: (1-101) facets, (1-102) facets, micro facets and *c*-plane growth region (see Fig. 1(a)). NanoXRD measurements revealed that lattice constants *a* and *c* clearly depend on those growth sectors (Fig. 1(b) and (c) show changes of *a* and *c* along with position X($\vec{c}$), respectively). Interestingly different behaviors of the lattice constants are observed from point 2 to 4 (marked by yellow circles in Figs. 1(b) and (c) which corresponds to the micro-facets area in Fig. 1(a)), while the SIMS results show that oxygen concentration [O] monotonically decreases across the region. Although overall lattice constants are roughly consistent with the [O] change, the local upturns of lattice constants imply that there is a stress evolution following Poisson effect, that is probably a stress relaxation, in the micro-facets growth area. A detailed model-based analysis is performed to describe the stress and oxygen concentration evolution related to different growth sectors.

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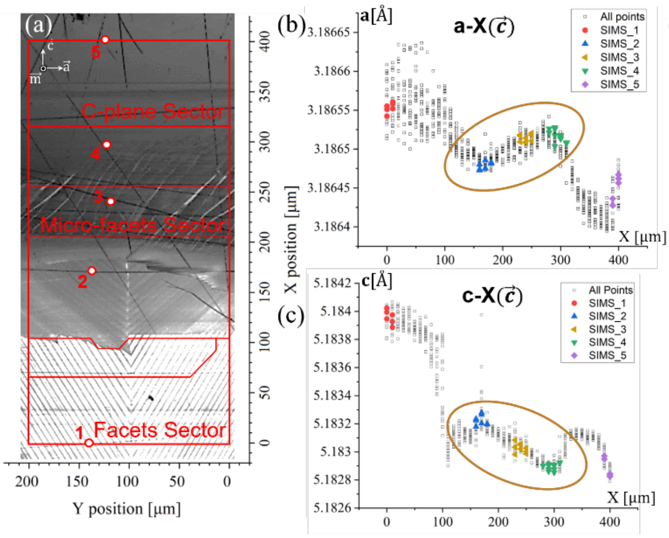

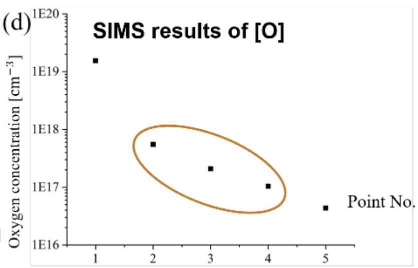

Fig. 1 (a) CL image of the coalescence area corresponding to the nanoXRD irradiation area. (b) *a*-X($\vec{c}$) plot. (c) *c*-X($\vec{c}$) plot. (d) SIMS results of the oxygen concentration [O] distribution from point 1 to 5 in (a).

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