Analysis of Crystal Structure Associated with Dislocation Gathering in Na-flux GaN by Nanobeam X-ray Diffraction

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[Introduction] GaN is widely used in electronic devices like vertical power devices, and high-speed transistors because of wide direct bandgap (~3.49 eV), high electron mobility (> 1000 $cm^2/V{\cdot}s$) and high critical breakdown field (~3.3 MV/cm). Mori *et al.* have successfully produced high quality GaN substrates in the developed Na-flux method with low dislocation density (<10^5 cm^{-2}) and long bending curvature (>30 m) [1]. This method combines the flux film coating (FFC) technique and the multi-point seed technique (MPST) in which coalescence between the initial pyramid GaN crystals grown above seeds is enhanced. Although the coalescence is important in controlling crystal quality, structure evolution during coalescence is still in lack of investigation. This research tries to analyze the crystal structural characteristics in coalescence areas by nanobeam X-ray diffraction (nanoXRD).

[Experiment] Fig. 1(a) compares analyzed positions of samples with respect to the pyramid structures for this work and the previous work [2][3], and the correlated multi-photon-excited photoluminescence (MPPL) image is shown in Fig. 1(b). This work focuses on the regions near the triple points of coalescence of three pyramids, contrary to the previous case for the coalesced region of two closest pyramids. NanoXRD measurements were done in SPring-8 BL13XU with a beam size around 250 (hor.)×220 (ver.) nm^2. Lattice constants were extracted from 2-200 and 2-202 diffractions of the cross-sectional sample with an interval of 5 μm by using reciprocal space maps.

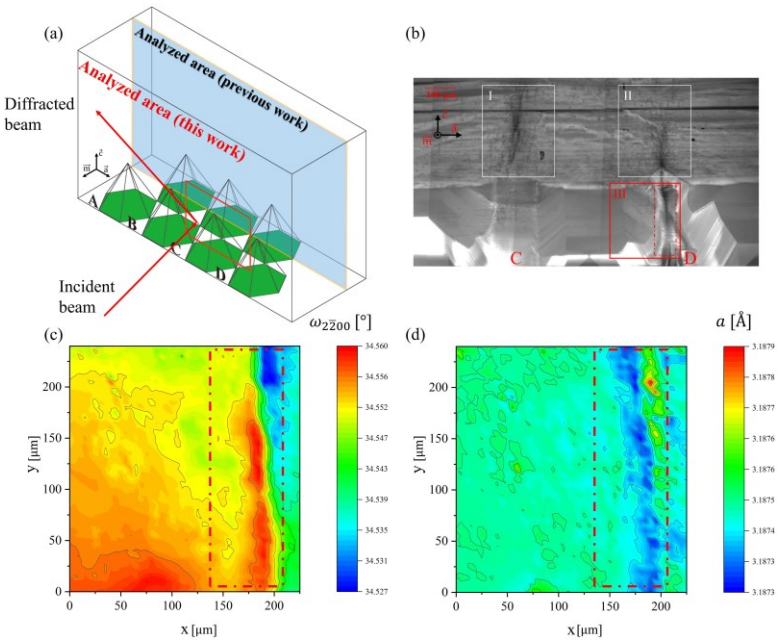

Fig. 1 (a) Schematic of analyzed regions, which indicates the position of pyramid structures and diffraction geometry in this work. (b) MPPL image of the sample including regions I to III where dislocations gather. The region for nanoXRD measurement is also shown as III which covers 225 × 240 $μm^2$. (c) Incident angle $\omega_{2\bar{2}00}$ peak distribution map of the region III. (d) Lattice constant *a* distribution map.

[Results and discussion] From the MPPL analysis, dislocation gathering is clearly observed in the sample crystal around the coalescence region (see region I, II and III in Fig. 1(b)), which cannot be observed in the previous case. One of nanoXRD measurements is done in the region III and a dislocation gathering region is marked by the dashed red rectangle. Interestingly, based on the incident angle ω peak distribution map from $2\bar{2}02$ diffraction [Fig. 1(c)], plane tilting significantly changes from the right to the left sides across the gathering area, which is related to the crystal coalescence. In contrast, in the *a*-axis lattice constant map [Fig. 1(d)], intense deformation of the lattice is limited within the dislocation gathering area. Those results show us the role of coalescence in modifying crystal structure and detailed investigations are necessary to understand the dislocation gathering behavior during coalescence.

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