Degradation of GaN Surface After Thermal Processes

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GaN has attracted attentions for RF and power devices owing to their superior material properties [1]. Especially, GaN grown on Si substrate has the cost effectiveness as well as a large diameter for the commercial production. Fabrication processes of GaN electronic devices have been composed of the cleaning, native oxide etching, dry etching, metal deposition, lift-off, alloy formation, post annealing, passivation, and electroplating. Thermal processes have been used as alloying ohmic contacts and a post-annealing method. We have already reported high-voltage GaN devices including high-electron-mobility transistors [2] and Schottky barrier diodes [3] using thermal processes. However, the effects of thermal processes on surface have not yet been clarified.

The purpose of the present work is to report the degradation of GaN surface after thermal processes. We grown GaN on Si substrate and compared material characteristics in GaN before and after thermal processes.

First, we grew GaN-based translation layer on Si(111). The thickness of the translation layer was about 1 μm. 630 nm-thick GaN was grown at the substrate temperature of 700 °C. Fig. 1 shows the cross-sectional view of GaN grown on Si(111) substrate. Then, the thermal treatment was performed to the GaN at 800, 900, 1000, and 1100 °C in the furnace. The ambient, pressure, and time of the thermal processes were N_2, atmospheric pressure, and 600 s, respectively.

We measured the surface morphology using scanning electron microscope (SEM) before and after thermal processes. Fig. 2 shows SEM images on GaN surface before and after thermal processes. When a temperature of the process was increased, the grain boundary was expanded and pits were generated as a result of the decomposition. The surface was eventually collapsed after the thermal process at 1100 ^{o}C. The decomposition on the GaN surface and the temperature during the epitaxial growth and the thermal process should be considered.

We measured and compared photoluminescence (PL) spectra in the GaN samples before and after thermal processes. The band-edge emission (BE) intensity at 3.4 eV was increased after thermal processes. The BE intensity was increased from 0.310 to 4.017 V/mW while full-width at half-maximum (FWHM) of BE was increased 7.4 to 9.1 nm due to the decomposition of 1100 °C process. The deep-level emission centered at ~2.2 eV of GaN in the normalized PL spectra was suppressed after thermal processes as shown in Fig. 3. This can be interpreted by the improvement on epitaxial layers. However, we consider that this phenomenon is caused by the increase of BE intensity or the decomposition on the surface associated with impurity-related recombination in GaN.

High-resolution X-ray diffraction was also used to inspect the crystal quality before and after thermal processes. The FWHM of (0002) ω-scan rocking curve was slightly increased from 1094 to 1148 arcsec due to the thermal process at 1100 °C. This change was not significant which was in the error range.

In conclusion, the thermal process did not affect the crystal quality of GaN, but this degraded the surface morphology. High-temperature processes of GaN-based devices should be considered on the surface of a gate-drain, gate-source, or anode-cathode region. The low-temperature process without degrading device performance is useful to suppress GaN decomposition.

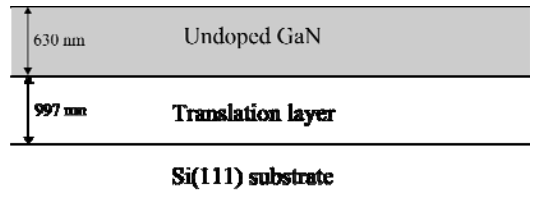

Fig. 1. Cross-sectional view of GaN grown on Si(111) substrate

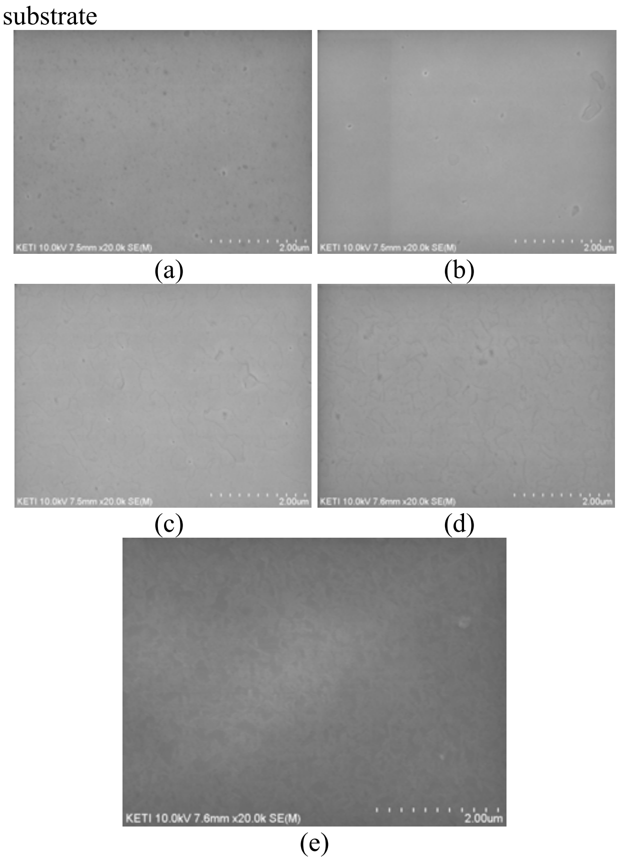

Fig. 2. SEM images of GaN (a) before and after thermal processes at (b) 800, (c) 900, (d) 1000, and (e) 1100 °C

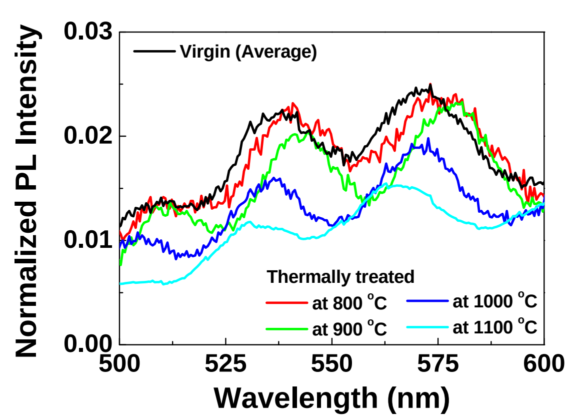

Fig. 3. Measured yellow luminescence of GaN before and after thermal processes

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