Effect of an Intermediate Layer on Cubic GaN Grown on GaAs (100): Substrate Protection and Strain Relaxation

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Cubic GaN can be obtained as a metastable phase by using cubic substrates such as GaAs (100) [1]. Suitable growth conditions, such as low V/III ratios and high growth temperatures are indispensable to stabilizing the cubic phase and improving the crystal quality [2]. Since the GaAs substrate is not very stable at high growth temperatures, a low-temperature buffer layer is commonly used for wetting the GaAs substrate and protecting it from thermal decomposition. However, at high growth temperatures over 900°C, the GaAs substrate cannot be completely protected because the buffer layer is very thin and is not uniform. The inevitable thermal nitridation roughens the substrate surface and thus degrade the cubic GaN quality. Furthermore, poor lattice mismatch and difference in thermal expansion coefficients between GaN and GaAs substrate make the epitaxial GaN layer quite strained. In this study, a GaN intermediate layer was introduced between the low-temperature buffer layer and the GaN epilayer. We showed that the quality of GaN epilayer was improved by using this technique due to the effect of substrate protection and strain relaxation.

Cubic GaN films were grown by low-pressure (160 Torr) metalorganic vapor phase epitaxy (MOVPE) using trimethylgallium (TMG) and 1,1-dimethylhydrazine (DMHy) as the Ga and N precursors, respectively. GaN was grown using a three-step growth process. After the deposition of a 20 nm-thick buffer layer at 575°C, an 0.2 μm-thick GaN intermediate layer was grown at a moderate temperature of 800~850°C. Finally, cubic GaN epitaxial layer was deposited at 980°C. Sample without the intermediate layer was also grown at 900°C for comparison. The cubic GaN was determined by scanning electron microscope (SEM), X-ray diffraction and photoluminescence (PL) measurements.

Figure 1 shows the cross-sectional SEM images of GaN grown on GaAs (100) substrates. The interface between the GaN and the GaAs substrate is very smooth owing to the introduction of the intermediate layer. In contrast, for the sample without this layer, 1-μm-size triangle voids, which have a reverse-mesa shape formed by the (111) facets, were observed. These voids probably become the seeds of incorporated hexagonal phase GaN and thus degrade the cubic GaN quality.

X-ray diffraction showed that all the two samples, with or without the intermediate layer, condensed mainly in cubic phase. As shown in Fig. 2, x-ray diffraction peak shift indicates the difference of residual strain inside the crystal. Although both the two samples were under a tensile biaxial strain, by using an intermediate layer, the strain $\varepsilon = (a - a_0) / a_0$ was reduced from -0.17% to -0.11%, where a_0 is the unstrained lattice constant of cubic GaN obtained by measuring x-ray diffraction of asymmetry (511) crystal plane.

Fig. 3 shows PL spectra of the two samples with and without the intermediate layer. First, improvement of optical quality by using the intermediate layer was confirmed. Secondly, the exciton peak energy of sample with intermediate layer is blueshifted by ~7 meV. This blueshift can be interpreted as the effect of the reduced tensile strain. Thus, all the SEM, X-ray diffraction and PL measurements showed that the crystal quality was improved successfully by using an intermediate layer.

References

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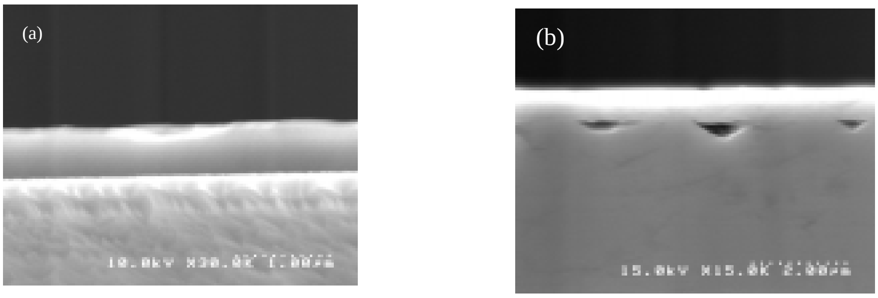

Fig.1. Secondary electron micrographs of cubic GaN grown on GaAs (100) substrates with (a) and without (b) the intermediate layer.

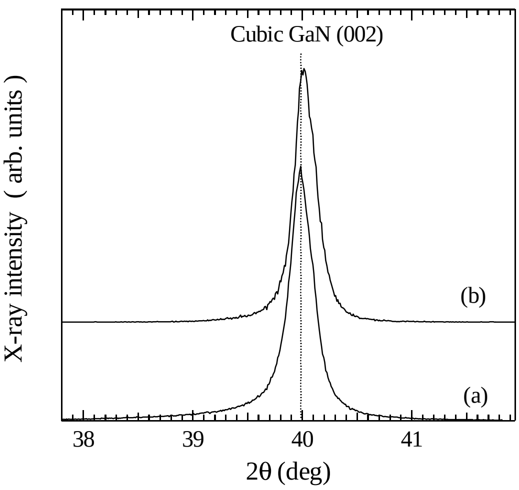

Fig.2. X-ray diffraction of GaN with (a) and without (b) the intermediate layer grown on GaAs (100) substrates. The residual strain results in the x-ray peak shift.

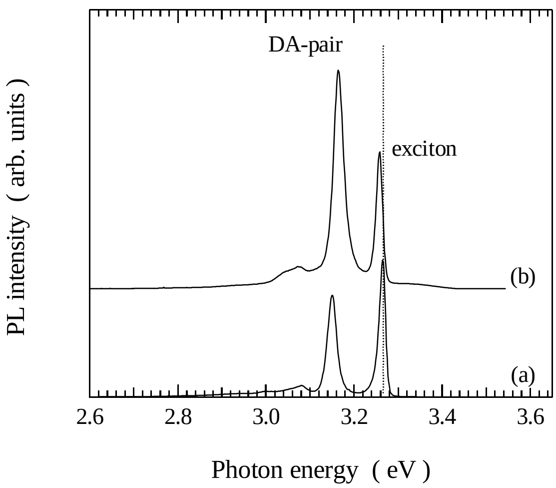

Fig.3. Low temperature photoluminescence spectra of cubic GaN with (a) and without (b) the intermediate layer grown on GaAs (100) substrates.