An Indium Surfactant Effect in Cubic GaN rf-MBE Growth

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Cubic GaN (c-GaN) have several advantages for the device application due to its higher crystallographic symmetry. However, the crystalline quality of the reported c-GaN layers were not good enough for the device applications because of the hexagonal GaN (h-GaN) phase mixing during growth [1]. Recently several improvements of the crystal quality of c-GaN by the As surfactant effect and the atomic hydrogen treatment of the GaAs surface have been reported [1,2]. Furthermore, we reported a suppression effect of the h-GaN mixing perpendicular to the {111}A planes by As_4 molecular beam irradiation during the c-GaN growth, and that the mixing nature strongly depend on the effective V/III ratio during the growth. The past experimental results strongly suggest that the h-GaN mixing perpendicular to the {111}B planes would be related with the surface morphology and / or the effective V/III ratio during growth. Certainly it is able to decrease the h-GaN mixing perpendicular to the {111}B planes in the growth under the low V/III ratio, however, the other problems occur during growth, such as the surface morphology degradation and the generation of Ga droplet [3,4]. On the other hand, improvement of morphological and optical properties of the h-GaN grown by MBE using In beam irradiation has been reported as a result of the In surfactant effect [5]. Therefore, the In beam irradiation in the c-GaN growth would be also effective for the flat surface formation and the control of V/III ratio without droplets generation to suppress the h-GaN mixing perpendicular to {111}B planes. In the present paper, we have reported the In beam irradiation effect as a surfactant during the c-GaN growth on the GaAs(001) substrates by rf-MBE.

GaN growth was carried out by a radio-frequency plasma-assisted molecular beam epitaxial (rf-MBE) system using the metal Ga, the metal In and the rf-nitrogen sources. The GaN layers were grown at 690℃ after a low temperature GaN buffer layer (LTBL) formation at 550℃ on the thermally clean GaAs (001) (2×4) surface under the As_4 molecular beam of 1.0×10^{-5} Torr. The In beam irradiation was carried out during both the c-GaN and the LTBL growth. The grown layers were characterized by a X-ray diffraction (XRD) method and an atomic force microscope (AFM).

Figure 1 shows the typical AFM images for the c-GaN layers grown (a) with and (b) without In beam irradiation, respectively. The surface morphology is clearly different in the both cases. The results indicate that the In beam irradiation strongly improve the surface morphology during the c-GaN growth under the N-rich growth conditions. The similar effect was also observed in the growth under the Ga-rich growth conditions, in which the Ga droplets generated on the surface. Figure 2 shows the full width of half maximum (FWHM) of θ-2θ XRD peaks from the c-GaN(002) layers grown under Ga-rich conditions as a function of the In beam intensity. Additional peaks from the In or the InGaN were not observed. The results indicate that the FWHM does not depend on the irradiated In beam intensity. Typical ω-2θ X-ray reciprocal space maps (RSMs) with <1-10> incident X-ray azimuth for the c-GaN layers grown with the In beam irradiation under (a) the Ga-rich condition, and (b) the N-rich condition, respectively are shown in Figure 3. A weak h-GaN mixing for {111}B planes can be observed as shown in Figure 3 (b). This result suggests that the In beam irradiation is not so effective for the h-GaN mixing under the N-rich growth conditions in spite of the improvement of the surface morphology and the FWHM of XRD patterns. This implies that the In irradiation may induce an additional process which vary the effective V/III ratio during growth under the N-rich conditions. Therefore, more precise control of the effective V/III ratio should be needed to suppress the h-GaN mixing.

In conclusions, we have investigated a surfactant effect of the In atoms during the c-GaN growth on the GaAs(001) substrates. The In beam irradiation is a very effective method to suppress the h-GaN mixing combined with the precise control of the effective V/III ratio.

References
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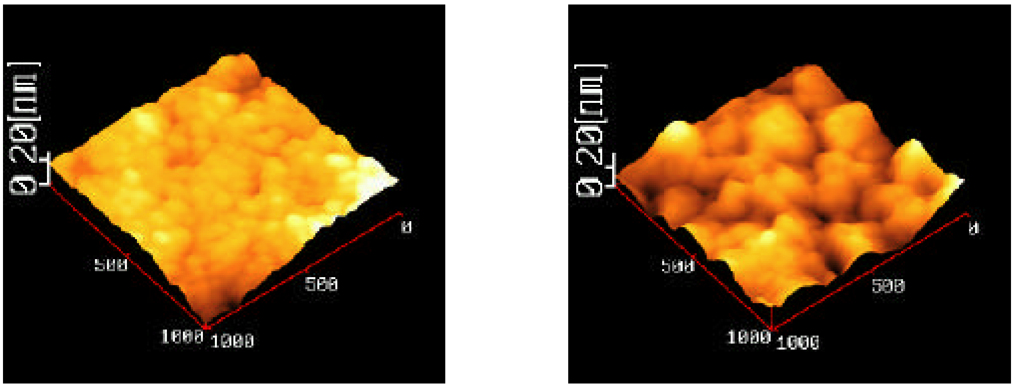


(a) (b)

Figure 1. AFM images for GaN layers grown (a) with and (b) without In beam irradiation

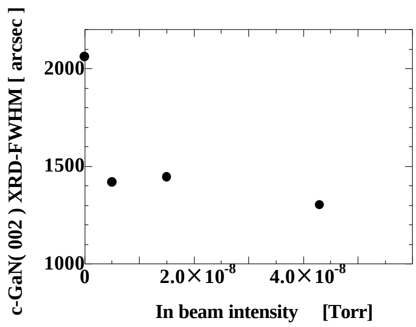
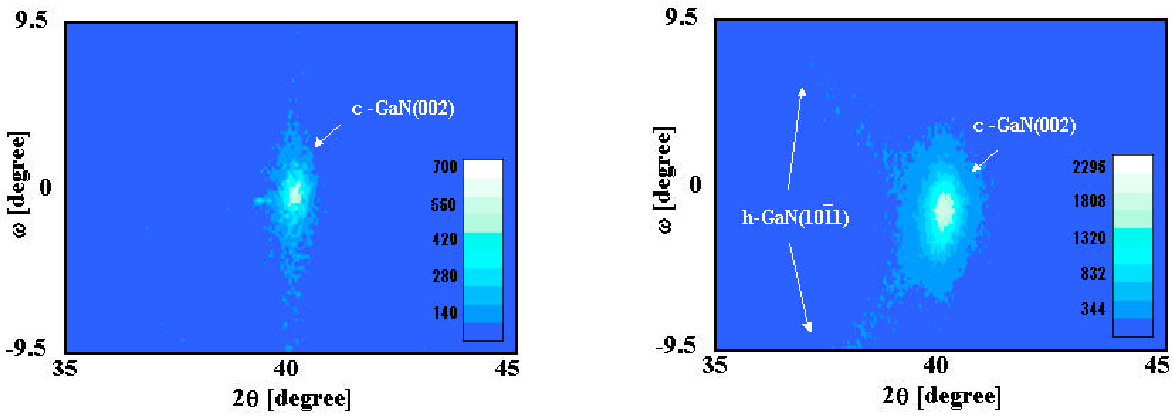


Figure 2. FWHM of θ - 2θ XRD c-GaN (002) Peaks as a function of In beam intensity



(a) (b)

Figure 3. Typical ω-2θ X-ray reciprocal space maps (RSMs) with <1-10> incident X-ray azimuth for GaN layers grown with In irradiation under the (a) Ga-rich and (b) N-rich condition.