Improvement of Crystalline Quality of AlN and High-Al-content AlGaN at High Growth Rate Using Horizontal High-flow-rate MOVPE System

Kazutada Ikenaga, Akira Mishima, Yoshiki Yano, Toshiya Tabuchi, and Koh Matsumoto
Taiyo Nippon Sanso Corporation
Tsukuba-city, Ibaraki, Japan
Email: Kazutada.Ikenaga@tn-sanso.co.jp

***Abstract*—The influences of the growth temperature of the buffer layer and the growth rate of AlN at 1300 °C on AlN crystalline quality were investigated. By using a horizontal high-flow-rate metal organic vapor phase epitaxy reactor, the growth rate of AlN was increased linearly up to 18 μm/h with increasing trimethylaluminum input partial pressure in spite of the high growth temperature of 1300 °C; the full width at half maximum of the X-ray rocking curve of AlN was almost unchanged. Moreover, the $Al_{0.5}Ga_{0.5}N$ layer was grown on AlN/sapphire and the atomic step was observed on the surface of AlN and AlGaN layers by atomic force microscopy.**

Keywords*—*AlN;AlGaN;MOVPE;high growth rate

I. Introduction

The crystalline quality of AlN and high-Al-content AlGaN as underlying layer of deep ultraviolet light emitting diodes should be improved for attaining high emission efficiency. It was reported that the threading dislocation density (TDD) in AlN can be reduced by increasing its layer thickness [1]. Recently, in order to achieve lower TDD in AlN, epitaxial lateral over growth technique has been developed using very thick AlN (i.e., over 10 μm) to obtain a flat surface [2]. However, in general, because of hazardous parasitic reactions between trimethylaluminum (TMA) and ammonia, it is difficult to grow AlN at a high rate and high temperature [3]. We previously reported that AlN and AlGaN can be grown at a high rate by using a high-flow-rate metal organic vapor phase epitaxy (MOVPE) reactor while suppressing the hazardous parasitic reactions [4]. In this study, we investigated the influences of the growth temperature of the buffer layer and the growth rate of AlN at 1300 °C on the AlN crystalline quality. In addition, we grew $Al_{0.5}Ga_{0.5}N$ layer on AlN/sapphire and investigated its surface morphology.

II. Experiment

We used a low-pressure MOVPE reactor that had a susceptor with the capacity of three 2-inch diameter wafers (SR4000HT, Taiyo Nippon Sanso). We grew 3-μm-thick AlN/100-nm-thick AlN buffer layer on c-plane sapphire substrate with an off-orientation of 0.15° towards the m-plane. The growth temperature of AlN buffer layer was varied from 890 °C to 980 °C, and that of 3-μm-thick AlN layer was 1300 °C. The 3-μm-thick AlN layer was grown in two steps: the growth rate of the first layer was 3.5 μm/h and that of the second layer was increased up to 18 μm/h. $Al_{0.5}Ga_{0.5}N$ layer of thickness 1.0 μm was grown on AlN at a growth rate of 3.5 μm/h. The crystalline quality of AlN was evaluated in terms of the full width at half maximum of the X-ray rocking curve (XRC-FWHM). The surface morphology was observed using an atomic force microscope (AFM) and a surface profiler.

III. Results and Discussion

Figure 1 shows the XRC-FWHM and surface roughness of AlN as a function of the growth temperature of AlN buffer layer. The XRC-FWHM for (10-12) direction was improved from 603 arcsec to 442 arcsec by decreasing the growth temperature. However, the surface roughness of the AlN sample grown at 890 °C was worse than that of the other samples. From these results, the optimal growth temperature of AlN buffer layer was found to be 920 °C. Figure 2 shows the growth rate and XRC-FWHM of AlN versus the TMA input partial pressure. The growth rate of AlN was increased linearly up to 18 μm/h with increasing TMA input partial pressure in spite of the high growth temperature of 1300 °C, and the XRC-FWHM was almost unchanged. These results indicate that the particle reaction in gas phase was well suppressed by high-flow-rate MOVPE growth. Figure 3 shows AFM images of AlN samples formed at various growth rates. The surface of AlN obtained at a higher growth rate became slightly rougher than those at lower growth rates. The surface roughness can be improved by optimization of the growth parameters such as V/III ratio and growth temperature. Figure 4 shows the AFM image of $Al_{0.5}Ga_{0.5}N$ grown on AlN at a growth rate of 3.5 μm/h. The atomic step was observed, but the surface was rougher than the AlN surface shown in Fig. 3 (a). To obtain smoother surface of AlGaN on AlN, further optimization of structure and growth conditions are necessary, which will be discussed in the presentation.

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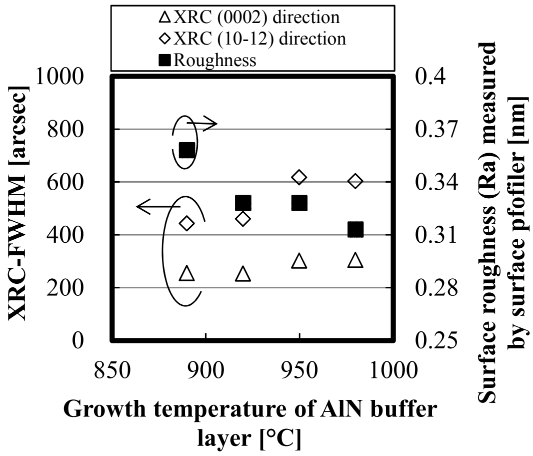


Fig. 1. XRC-FWHM and surface roughness as a function of growth temperature of AlN buffer layer.

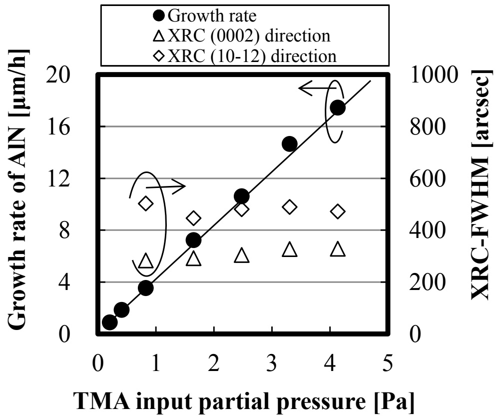
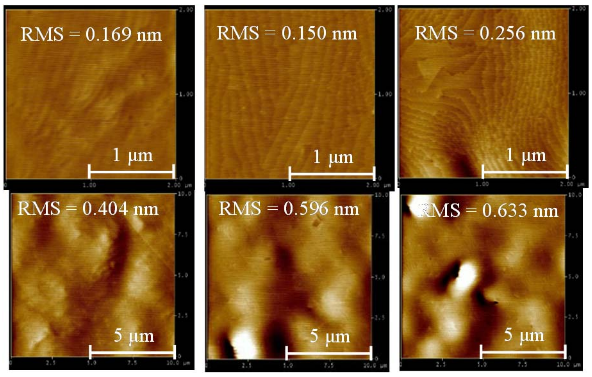


Fig. 2. Growth rate and XRC-FWHM versus TMA input partial pressure.



(a) (b) (c)

Fig. 3. AFM image of AlN grown at (a) 3.5 µm/h, (b) 15 µm/h and (c) 18 µm/h.

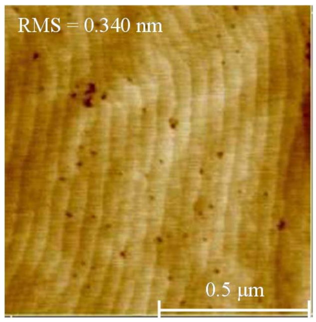


Fig. 4. AFM image of $Al_{0.5}Ga_{0.5}N$ grown on AlN/sapphire at 3.5 µm/h.