Regrowth of High-Al-content AlGaN and AlN on High-quality AlN Template Fabricated by Annealing at 1700 °C under Nitrogen Ambient

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High-quality AlN and AlGaN are required as the underlying layers of deep ultraviolet LEDs (DUVLEDs) to achieve high emission efficiency. Recently, it was reported that the crystalline quality of sub-micrometer-thick AlN could be improved by high-temperature annealing under N_2-CO [1]. In this study, we examined $Al_{0.6}Ga_{0.4}N$ and AlN layers grown on high-quality AlN templates, which were fabricated using high-temperature annealing under pure N_2 gas.

We used a low-pressure metalorganic chemical vapor deposition (MOCVD) reactor (SR4000HT, Taiyo Nippon Sanso), and an annealing furnace (STA1700, Taiyo Nippon Sanso). The 300-nm-thick AlN layers were grown on 2-inch sapphire substrates and subjected to annealing at 1700 °C for 1 h in pure N_2 atmosphere. We grew 2.6-μm-thick AlN on this annealed template at 1300 °C. A 2.3-μm-thick $Al_{0.6}Ga_{0.4}N$ layer was also grown on the annealed AlN template at 1150 °C. The crystalline quality was characterized in terms of the full width at half maximum of the X-ray rocking curve (XRC-FWHM). The surface morphology was observed using a scanning electron microscope (SEM) and a Nomarski microscope.

The effect of high-temperature annealing on the XRC-FWHM of the AlN template was investigated. By annealing at 1700 °C, the XRC-FWHM of the (0002) plane was decreased from 342 to 219 arcsec, and that of the (10-12) plane was drastically decreased from 923 to 480 arcsec. In addition, the XRC-FWHMs of the (0002) and (10-12) planes throughout the wafer were less than 250 arcsec and less than 500 arcsec, respectively. After annealing the 300-nm-thick AlN on sapphire, the surface morphology was not drastically changed. In the regrown AlN on the AlN template, the XRC-FWHMs of the (0002) and (10-12) planes were 153 and 437 arcsec, respectively. Cracks were not observed at any point on the wafer surface after the regrowth of 2.6-μm-thick AlN. By contrast, many cracks were observed in the AlN directly grown on sapphire. In regrown $Al_{0.6}Ga_{0.4}N$, no cracks were observed, as with the AlN. These results indicate that AlN templates fabricated by high-temperature annealing can promote the enhancement of production quality of DUV-LEDs. Other details will be presented at the conference.

[1] H. Miyake, et al., Appl. Phys. Express 9, 025501 (2016)

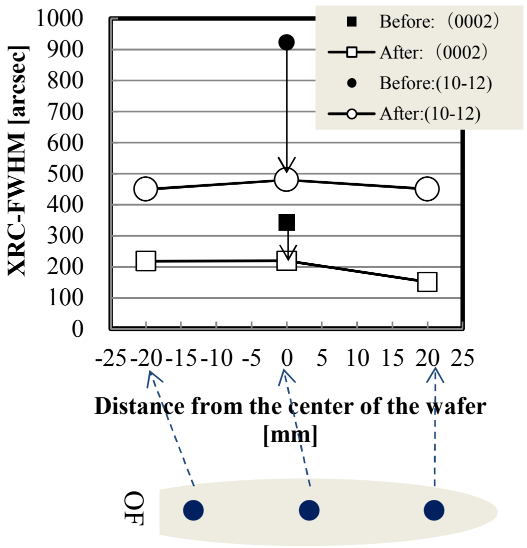
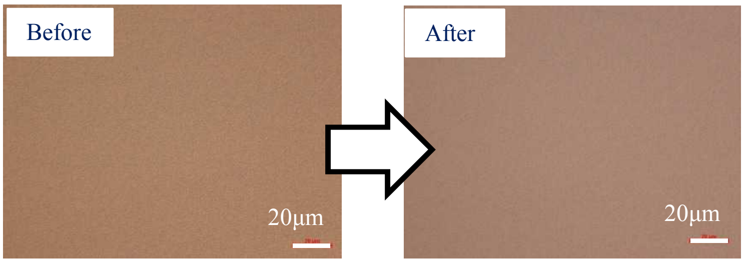
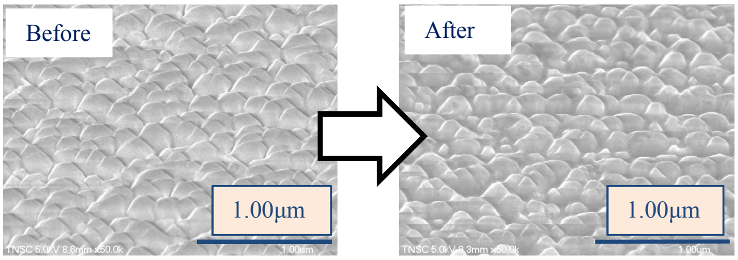


Fig. 1 XRC-FWHM of 300-nm-thick AlN before and after annealing at 1700 °C



(a) Nomarski image



(b) SEM image

Fig. 2 Surface morphology of the AlN layer on sapphire before and after annealing at 1700 °C

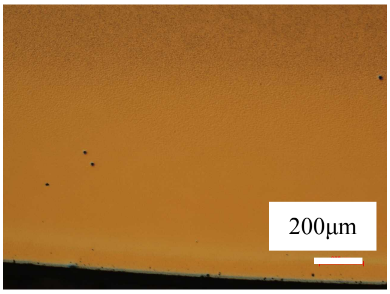


Fig. 3 Nomarski image of the wafer edge of the regrown AlN

(No cracks are observed at any point on the wafer surface.)