Fabrication of face-to-face annealed sputter-deposited AlN templates with screw-dislocation densities of 10^3-10^4 cm^{-2}

H. Miyake[1*], K. Uesugi[2,3], K. Shojiki[1], S. Xiao[1], T. Nakmura[1,2]
[1]Graduate School of Engineering, Mie University, Tsu, Japan
[2]Mie Regional Plan Co-Creation Organization, Mie University, Tsu, Japan
[3]Graduate School of Regional Innovation Studies, Mie University, Tsu, Japan
*email: miyake@elec.mie-u.ac.jp

To realize high-efficient, high-power, and reliable deep-ultraviolet light-emitting devices, it is necessary to grow high-crystalline-quality AlGaN. For this purpose, preparing AlN templates with low threading dislocation densities (TDDs) is mandated. As an alternative to the conventional metalorganic vapor phase epitaxy (MOVPE)-prepared AlN templates, we have proposed a fabrication technique combining sputter deposition of AlN films on sapphire substrates and face-to-face high-temperature annealing [1]. The face-to-face annealed sputter-deposited AlN templates (FFA Sp-AlN) have achieved one order of magnitude lower TDD than that of the typical MOVPE-grown AlN on sapphire substrates. Furthermore, sputter deposition and high-temperature annealing are simple and cost-effective processes compared with the MOVPE. In this paper, we will demonstrate the recent progress on the quality improvement of FFA Sp-AlN and UV-C LED fabricated on the FFA Sp-AlN.

Reduction of TDDs in FFA Sp-AlN and surface flattening of AlGaN grown on the FFA Sp-AlN play important roles to achieve a high external quantum efficiency (EQE). The TDDs in FFA Sp-AlN decrease with the increase of the AlN film thickness and the increase of the annealing temperature [2,3]. Additionally, we adopted the double sputtering and annealing method [4] and the thermal cycle annealing (TCA) method [5]. With these two approaches, the minimum TDD of 4×10^7 cm^{-2} was realized with the AlN film thickness of 1.2 μm. For the sputtering temperature of 750°C and thickness of 600-800 nm, and then TCA at 1600-1700°C for 36 h, we achieved the FFA Sp-AlN templates with screw and total TDDs of 10^3-10^4 and approximately 1×10^8 cm^{-2}, respectively.

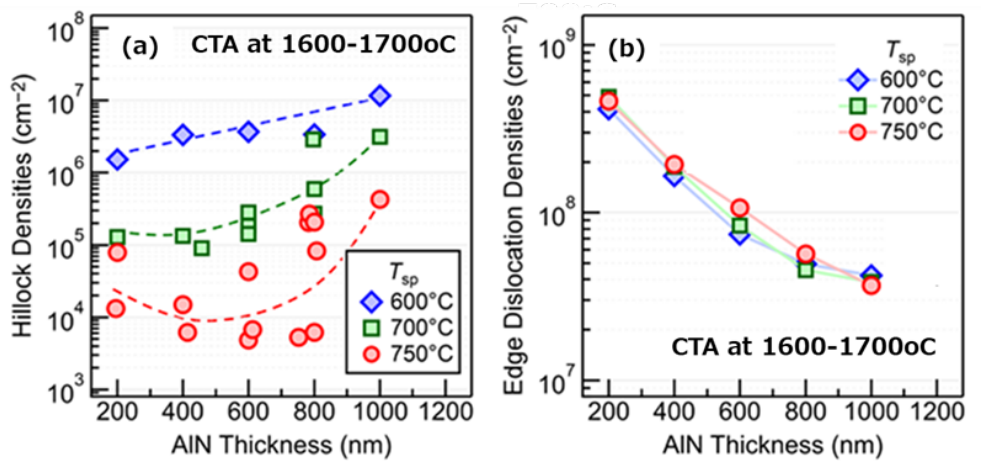

Figure 1: (a) Hillock densities on the $Al_{0.70}Ga_{0.30}N$ films estimated from the Nomarski microscopy images. The hillock density corresponds to the screw dislocation densities in the FFA Sp-AlN. (b) Edge-type dislocation densities of the FFA Sp-AlN estimated from XRC-FWHM.

References

[1] H. Miyake et al., J. Cryst. Growth **456**, 155 (2016). [2] K. Uesugi et al., Appl. Phys. Express **12**, 065501 (2019).[3] K. Uesugi et al., Jpn. J. Appl. Phys. **60**, 120502 (2021). [4] D. Wang et al., Appl. Phys. Express **13**, 095501 (2020). [5] D. Wang et al., Appl. Phys. Express **14**, 035505 (2021).[6] K. Uesugi et al., Appl. Phys. Lett. **116**, 062101 (2020).