Aluminiumization-Assited Influence on the Crystalline Quality of the AlN Template Grown on c-Sapphire

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AlGaN-based LEDs are promising alternatives to toxic mercury-based UV light sources, supporting the Minamata Convention 2020 and the United Nations' Sustainable Development Goals (SDGs). Recently, far-UVC AlGaN-based LEDs have gained attention for their harmless effects on humans while effectively disinfecting multidrug-resistant organisms, including fungi (Candida auris) and viruses (SARS-CoV-2). However, their adoption is limited by low efficiency, primarily due to non-radiative recombination in the multiquantum well (MQW) active region, often caused by high threading dislocation density (TDD), which also leads to heat generation. A major source of these dislocations is the AlN underlayer, where a high TDD (~10^9 cm^{-2}) often occurs due to the large lattice mismatch between AlN and c-sapphire [1]. For mass production of AlGaN-based devices, improving the AlN underlayer quality is crucial. While high-quality AlN growth on single-crystal AlN substrates or thick AlGaN buffer layers has been explored, these methods remain prohibitively expensive for commercial-scale production. In contrast, AlGaN grown on low-cost AlN templates on c-sapphire offers scalability, affordability, and excellent UV transparency. Our group has previously optimized AlN template growth on c-Sapphire using MOCVD [2]. However, to capitalize on AlN templates benefits for industrial applications, further improvements in the crystal quality of AlN films grown on c-Sapphire substrates are necessary. In this work, AlN layers were grown on c-sapphire by adopting a new strategy introducing a thin Aluminiumization process before the final AlN layer using MOCVD. During the growth, trimethylaluminum (TMA) was directly introduced without ammonia (NH_3) flow, after the nucleation (See Figure 1). These new templates demonstrate the XRD FWHM values of 156 arcsec for the (002) plane and 485 arcsec for the (102) plane, indicating improved crystalline quality, when compared to the AlN template obtained by conventional method (XRD FWHM values for the (002) plane = 253 arcsec and for the (102) plane = 574 arcsec). The surface roughness is also improved, with a root mean square (RMS) roughness of 0.08 nm (See Figure 2), which is beneficial for the subsequent growth of far-UVC and UVB LED with higher internal-quantum efficiency (IQE). **References:** [1]. Khan et al. J. Mater. Chem. **C**, 7, 143-152 (2019). [2]. H. Hirayama, et al., APL **91,** 071901 (2007).

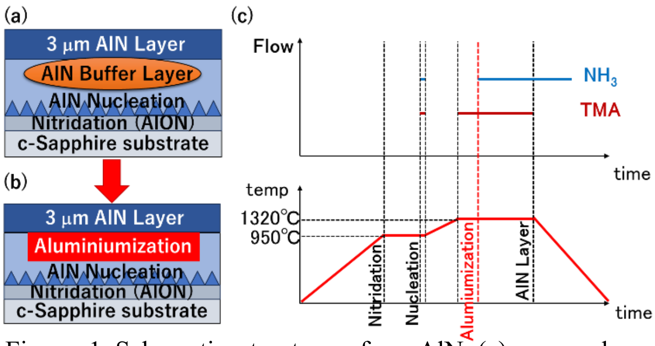

Figure 1 Schematic structure of an AlN (a) grown by conventional method, (b) grown by new method, and (c) flow sequence of NH_3 and TMA during the AlN growth.

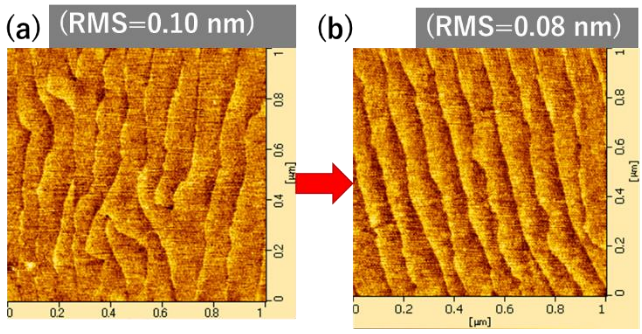

Figure 2 AFM images of the AlN templates grown (a) by conventional method and (b) by this new method.