# Vapor phase epitaxy of AlN thick films from environmentally-friendly sources of Al powders and nitrogen gas

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Aluminum nitride (AlN) is a promising material for ultraviolet (UV) emitters due to its large direct band gap of ~6 eV at room temperature. However, the lack of suitable substrates is a critical problem for the heteroepitaxial growth of AlN-based heterostructures. The large mismatches in both the thermal expansion coefficients and lattice parameters between AlN and substrates such as sapphire or Si cause cracks and high-density defects in the AlN films. Therefore, AlN bulk crystals for homoepitaxy are expected. However, the current common growth methods of AlN bulk crystals including hydride vapor phase epitaxy and sublimation have some restrictions: dangerous source precursors, extreme high growth temperatures up to 2000 °C, etc.

In this study, we proposed a new approach of AlN thick film growth, where only Al powders and nitrogen gas are used as source materials. A simple thermodynamic analysis suggested that a reaction of $Al+1/2N_2=AlN$ is possible at a reasonable temperature. However, if nitrogen gas is directly supplied onto Al powders, AlN is formed on the powder surface. Therefore, Al vapor and nitrogen gas should separately be transferred onto the substrate surface. To do this, we constructed a growth machine equipped with two temperature zones; one is for source and the other is for growth. Al powders placed in the source zone are heated at 1400°C to generate Al vapor. Then, Al vapor was transferred with argon gas to the growth zone, where the Al vapor met separately-supplied nitrogen gas, and AlN film was grown on sapphire (0001) substrate at 1550°C. The growth pressure was kept at 10 kPa. Argon carrier gas was essential to avoid premature reactions between Al vapor and nitrogen gas. Furthermore, the optimization of the flow rate of argon greatly influenced the growth behavior, suggesting the importance of fine tuning of the V/III ratio.

Optimizing the growth condition achieved a growth rate of 16 μm/h. Figure 1 shows a cross sectional scanning electron microscopy (SEM) image of a grown 16-μm-thick AlN. The structural properties of the fabricated films were assessed by x-ray diffraction (XRD) measurements. The XRD $2\theta$-$\omega$ profile indicated successful growth of AlN. Besides, the $\phi$ scan of the AlN $\{1\bar{1}02\}$ asymmetric planes showed that the crystal was in the single phase exclusive of other rotation domains. Figure 2 displays XRD $\omega$-scan profiles of the AlN (0002) symmetric and $(1\bar{1}02)$ asymmetric planes, which have full widths at half maximum of 309 and 318 arcsec, respectively. From these values, the edge and screw dislocation densities were estimated to be $6.0\times10^8$ and $2.1\times10^8/cm^2$, respectively. These results strongly suggest that this new method can be used for AlN bulk growth.

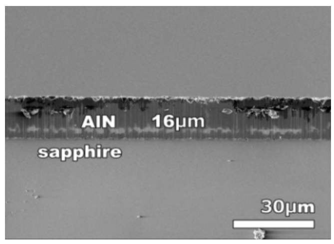

Fig.1. SEM cross-sectional image of the AlN thick film grown on c-plane sapphire.

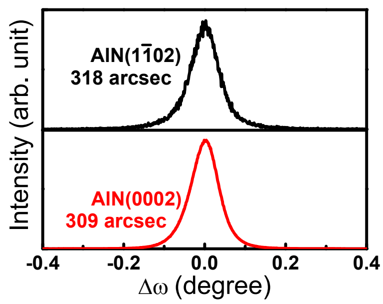

Fig.2. XRD ω-scan profiles of the grown AlN film.