Thickness Dependence on Crystalline Quality and Residual Stresses of AlN Films Deposited by Pulsed DC Reactive Sputtering

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AlN is expected to be one of candidate materials as a substrate for AlGaN based UV-LED and SAW devices owing to its wide band gap energy, high UV transparency, low lattice mismatch with AlGaN, and high surface acoustic wave velocity. Previously, the authors reported the polarity inversion of AlN layer grown on a nitride *a*-plane sapphire substrate [1] using pulsed DC reactive sputtering by varying the oxygen partial pressures (P_{O_2}) [2]. AlN films sputtered at low P_{O_2} of 5.0×10^{-10}-5.6×10^{2} Pa (at P_{total} of 10^5 Pa) had nitrogen (−c)-polarity. The best crystalline quality for nitrogen (−c)-polar AlN film was achieved at P_{O_2} of 5.0×10^{0} Pa. Aluminum (+c)-polar AlN was grown at the high P_{O_2} of 9.4×10^{3} Pa. However, the AlN film sputtered at the high P_{O_2} had high residual tensile stress of 17 GPa along the *c*-axis and compressive stress of 10 GPa along the *a*-axis. AlN film sputtered at the high P_{O_2} also had a polycrystalline at the top part of AlN film. The purpose of this research is to investigate the thickness dependence of crystalline quality and residual stresses of AlN films deposited by pulsed DC reactive sputtering.

AlN films were sputtered on a nitride *a*-plane sapphire substrate at 823 K and 600 W of pulsed DC power with a frequency of 100 kHz and duty ratio of 60%. The oxygen partial pressure (P_{O_2}) was kept at 9.4×10^{3} Pa in the Ar-50 vol%N_2 mixture gases. The total pressure (P_{total}) was kept at 0.6 Pa. The thickness of AlN films were varied at 200, 300, and 1300 nm. The AlN film with two layer structures was also fabricated with a first 200 nm-thick AlN sputtered at P_{O_2} of 9.4×10^{3} Pa following by 1100 nm-thick AlN sputtered at P_{O_2} of 5.0×10^{0} Pa simultaneously to maintain crystalline part until the AlN film reach the thickness of 1300 nm. The XRC-FWHM measurements were done to obtain the crystalline quality of AlN films. The lattice constants *a* and *c* of the sputtered AlN films were calculated using the θ values of the (10−12) and (0002) of the AlN films obtained from the 2θ-ω scan of the XRD measurement following a Bragg's law. The residual stresses along the *a*- and *c*-axes of sputtered AlN films were calculated at room temperature (RT) using a comparison with those of AlN bulk values.

The crystalline quality and the residual stresses along *a*- and *c*-axes of the AlN films increase with increasing thickness of AlN film. The best crystalline quality was achieved at the thickness of 200 nm with AlN (0002) and (10−12) XRC-FWHM values of 47 and 637 arcsec, respectively. The peak position of AlN (0002) shifted towards lower angles in 2θ–ω scan with increasing thickness. Therefore, the tensile residual stress along *c*-axis of AlN sputtered film increases owing to higher peening effect as the thickness increases. The AlN (0002) and (10−12) XRC-FWHM values of AlN film with two layer structures were 299 and 1696 arcsec, respectively. Among 1300 nm-thick AlN films, AlN film with two layer structures has the low residual tensile stress of 4 GPa along the *c*-axis and a compressive stress of 5 GPa along the *a*-axis.

References

1) H. Fukuyama, *et al.*: J. Appl. Phys. **107** (2010) 043502-1- 043502-7.

2) M. Noorprajuda, *et al.*: Abstracts of 12th International Conference on Nitride Semiconductors, Strasbourg, (2017), A 1.49.

