Supplementary Material to Submission #12981

"Low-temperature high-quality epitaxial AlN films deposited by plasma-enhanced atomic layer deposition"

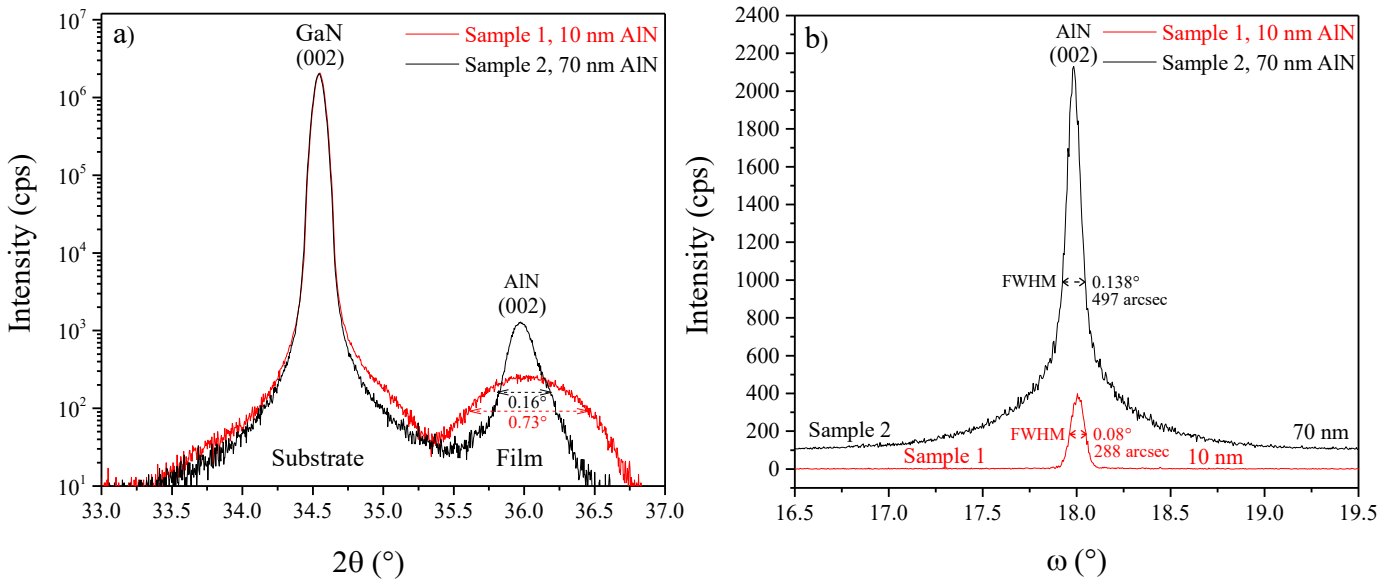

FIG. 1. (a) HRXRD θ–2θ scans of AlN (002) reflection for the 10 nm (sample 1) and 70 nm (sample 2) films, along with the GaN (002) substrate peak, plotted on a logarithmic intensity scale.

The 10 nm AlN film exhibited a broader (002) peak compared to the 70 nm film in agreement with thickness-limited out-of-plane coherence.

(b) HRXRD rocking-curve measurements of the AlN (002) peak for both samples. Threading dislocation densities are estimated to be 1.81–5.38 × 10^8 cm^{-2}, comparable to those of the GaN template, indicating preservation of structural quality during PEALD growth.

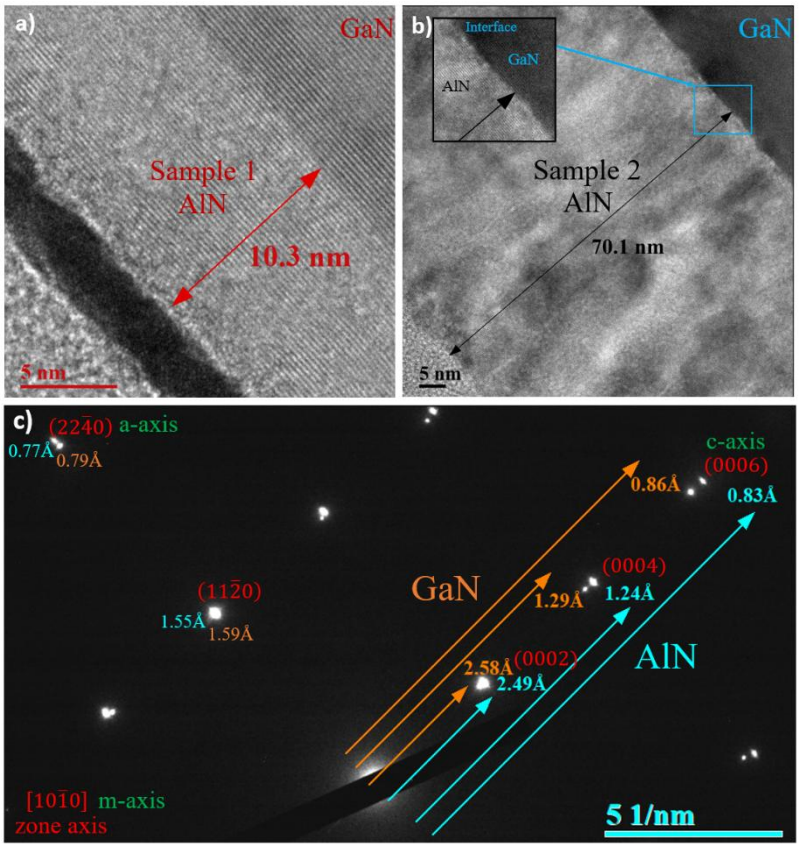

FIG.2. (a) Cross-sectional HRTEM image of sample 1 showing the AlN/GaN interface.

(b) HRTEM image of sample 2, with the inset showing a magnified view of the interface. Clear lattice fringes and an abrupt interface are observed in both samples, suggesting high-quality epitaxial growth.

(c) SAED pattern acquired from sample 2, showing diffraction spots corresponding to AlN and GaN planes.

The SAED pattern exhibits well-defined diffraction spots with in-plane rotational symmetry, consistent with epitaxial AlN growth on GaN.

The observed epitaxial alignment and high crystalline quality are desirable for optoelectronic device applications due to reduced defect density.

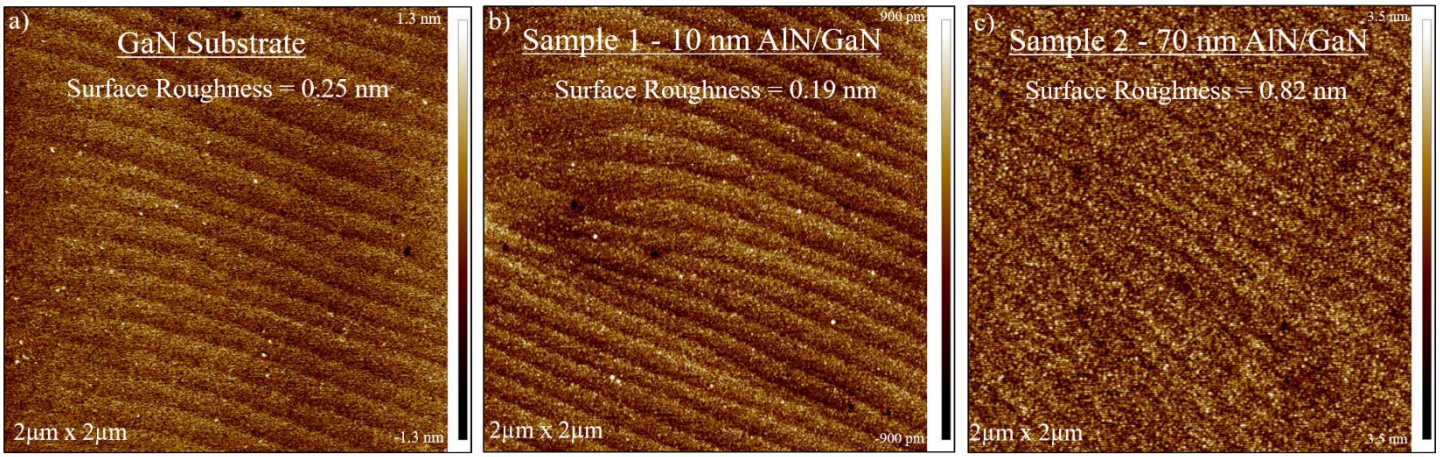

FIG. 3. AFM images showing the surface topography of (a) the bare GaN substrate, (b) sample 1 - 10 nm AlN on GaN and (c) sample 2 - 70 nm AlN on GaN.

The average surface roughness of the GaN substrate was 0.25 nm, while the AlN films exhibited roughness values of 0.19 nm for the 10 nm film and 0.82 nm for the 70 nm film.

The smooth AlN surface morphologies observed over a wide thickness range at low deposition temperature demonstrate the capability of PEALD to maintain high-quality interfaces.

* The Supplementary Material presents the figures published in Ref. [1].

References:

[1] Pini Medved, Silvia Piperno, Valentina Korchnoy, Gili Cohen-Taguri and Asaf Albo, "Low-temperature high-quality epitaxial AlN films deposited by PEALD," *Appl. Phys. Lett.* 127(23), 232104 (2025).

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[6] H.-Y. Shih, W.-H. Lee, W.-C. Kao, Y.-C. Chuang, R.-M. Lin, H.-C. Lin, M. Shiojiri, and M.-J. Chen, "Low-temperature atomic layer epitaxy of AlN ultrathin films by layer-by-layer, in-situ atomic layer annealing," *Sci. Rep.* 7(1), 39717 (2017).