<u>Supplemental materials to Submission # 10907</u>: "Towards ultra-low resistivity of titanium nitride PEALD layers grown on an amorphous SiO_2 substrate with aluminum nitride interfacial layer"

References:

[1] V. Korchnoy, I. Popov, M. Koifman-Khristosov, and M. Lisiansky, High Quality TiN Plasma Enhanced Atomic Layer Deposition on SiO_2 Substrate with AlN Interfacial Layer via in situ Atomic Layer Annealing, Proceedings of AVS 24th International Conference on Atomic Layer Deposition (ALD 2024), Helsinki, Aug 3-7, 2024

[2] H. Van Bui; F. B. Wiggers, A. Gupta, M. D. Nguyen, A. A. I. Aarnink, M. P. de Jong, A. Y. Kovalgin, Initial growth, refractive index, and crystallinity of thermal and plasma-enhanced atomic layer deposition AlN films, J. Vac. Sci. Technol. A 33, 01A111 (2015) https://doi.org/10.1116/1.4898434

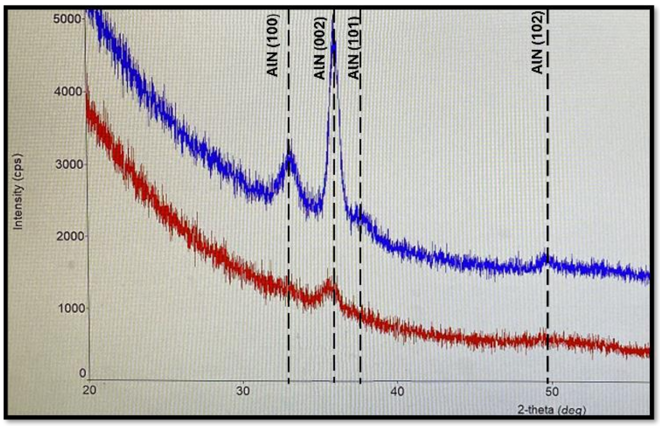

FIG. 1. XRD spectra measured using gracing incidence angle XRD scan mode (ω =0.5°) of AlN layer deposited by PEALD (N2/Ar plasma, power 300 W, at 300 °C, TMA precursor).
Red line – 12 nm AlN thickness; blue line – 66 nm AlN thickness. The peaks of hexagonal AlN are marked. Increasing the AlN thickness leads to better texturing of the film, which is indicated by rising and narrowing of the XRD peaks.

Table 1. Properties of PEALD layers deposited on SiO_2/Si substrate (Sample 1) and on sapphire (Sample 2)

Sample	Layers	Number of deposited cycles	Layer thickess measured in TEM, nm	Layer thickess measured by ellipsometry, nm	Layer thickness measured by XRR, nm	Layer density measured by XRR, g/cm^3	TiN resistivity as grown, μΩ.cm	TiN resistivity postdeposition annealing, μΩ.cm
Sample 1 (PEALD N2/Ar plasma on SiO2/Si substrate)	AlN	150	7.8 - 8.4	7.9	8.8	3.28	84	84
	TiN	250	14.8 - 16.1		14.6	5.26		
Sample 2 (PEALD N2/Ar plasma on sapphire substrate)	AlN	150	6.8 - 7.5	7.1	7.5	3.32	10.5	10.4
	TiN	250	14.7 - 15.7		14.3	5.2		

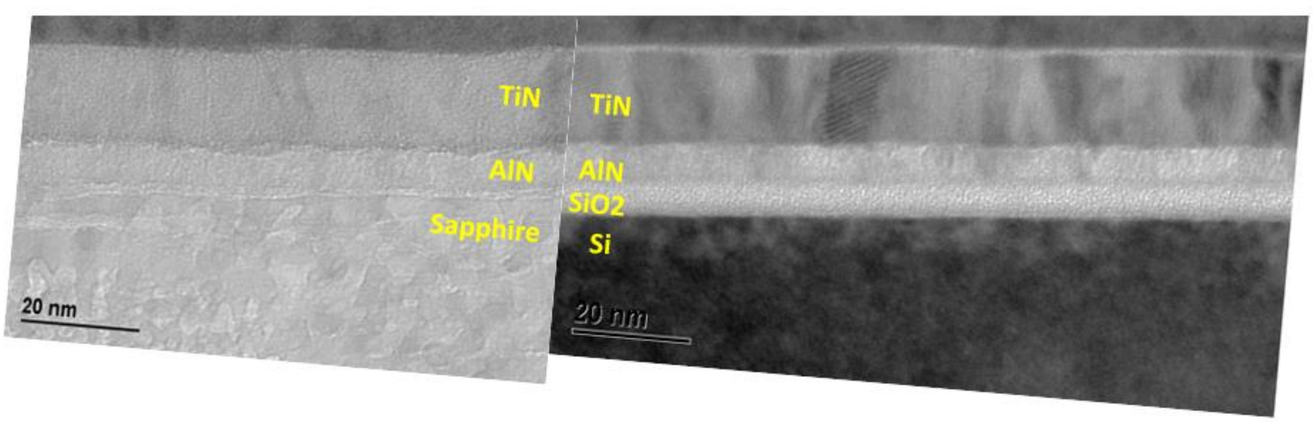

FIG.2. BF TEM micrographs of the TiN/AlN films grown on SiO_2/Si substrate (right) and on sapphire substrate (left) with N2 plasma.
Sapphire substrate initiated epitaxial-like growth. In the case of SiO_2/Si substrate AlN layer is much less uniform, growth of TiN is less related to AlN

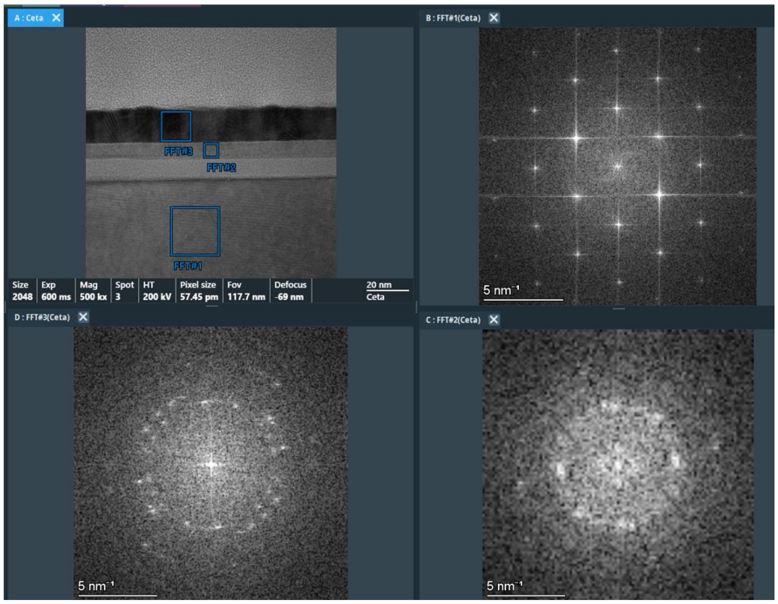

FIG.3. HR TEM micrograph and FFT analysis of TiN/AlN film grown on SiO_2/Si substrate. AlN layer thickness is about 8 nm. FFT1, FFT2, FFT3 are taken from the areas marked on TEM image:
FFT1 – Si substrate;
FFT2 – AlN layer;
FFT3 – TiN layer.
AlN grown on an amorphous substrate is poorly textured.
TiN is almost not structurally related to AlN IL, the extent of texturing is low.

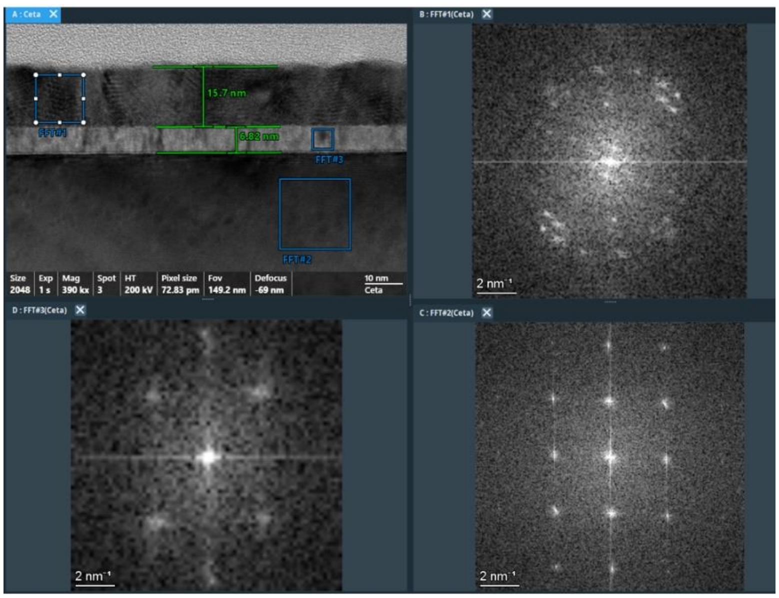

FIG.4. HR TEM micrograph and FFT analysis of TiN/AlN film grown on a sapphire substrate. AlN layer thickness is about 7nm. FFT1, FFT2, FFT3 are taken from the areas marked on the TEM image:
FFT1 – TiN layer;
FFT2 – sapphire substrate;
FFT3 – AlN layer.
AlN is perfectly aligned with the sapphire substrate, is highly textured and almost single crystalline.
TiN is structurally related to AlN IL and sapphire, textured as well. It preserves mosaicity of ~15 nm grains.

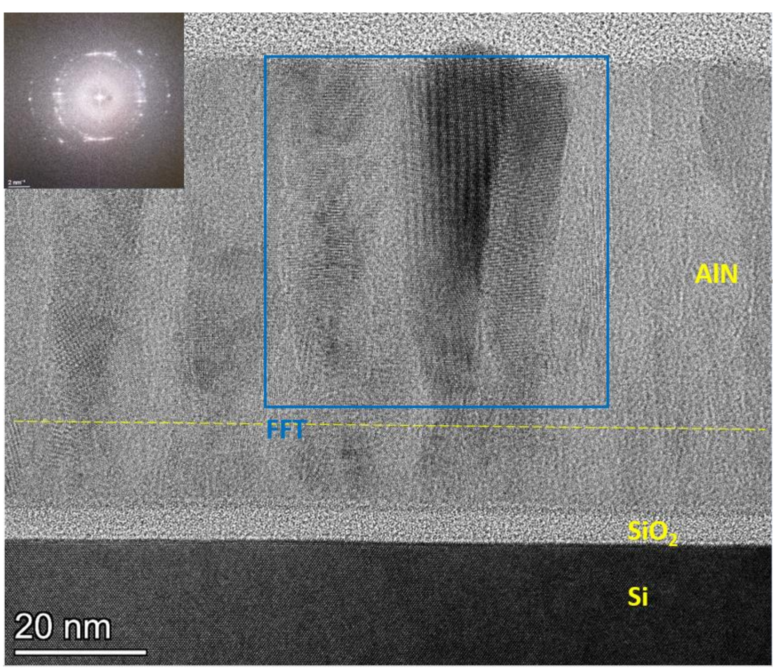

FIG.5. HR TEM micrograph and FFT analysis (inset) of AlN film grown on SiO_2/Si substrate.
AlN thickness is ~ 66 nm.
The AlN grows poorly texturized up to the layer thickness of ~ 20 nm.
Highly texturized columnar growth of AlN is observed when the layer thickness becomes greater than 20-25 nm.