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Plasma-based substrate modification for highly c-axis oriented growth of AlN and $Al_{1-x}S_{cx}N$ thin films by reactive magnetron sputtering

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Highly piezoelectric wurtzite-type $Al_{1-x}Sc_xN$ thin films (d_{33}=27.6 pC/N for x=0.43 [1]) are a promising alternative to AlN in different microelectromechanical systems (MEMS), such as surface acoustic wave (SAW) or thin film bulk acoustic wave resonators (TFBAR) used in RF filtering, sensing, and energy harvesting applications, allowing smaller and more efficient devices to be produced. However, different crystal structures of binary components, i.e. wurtzite-type AlN and cubic ScN result in formation of metastable ternary $Al_{1-x}Sc_xN$ prone to phase separation and elemental segregation. It is well known, that the well-ordered microstructure and high degree of c-axis orientation in piezoelectric AlN thin films directly correlates with higher electromechanical coupling and lower acoustic losses. Achieving high material quality becomes even more challenging for metastable materials such as $Al_{1-x}Sc_xN$. After first eliminating the misoriented grains in sputtered $Al_{1-x}Sc_xN$ thin films by tuning Ar/N_2 gas ratio and target-to-substrate distance [2,3], we aim to further enhance the crystalline quality of our AlScN thin films by using plasma-based substrate modification. In this work, reactive pulsed-DC magnetron sputtering was used to grow AlScN thin films on Si(001) and Al_2O_3(0001) substrates with thicknesses up to 1000 nm. *In-situ* inductively coupled plasma (ICP) soft etch with Ar, N_2, and H_2 gasses was used to treat the substrates prior to growth and the changes in the film nucleation behavior and how the quality of subsequently grown $Al_{1-x}Sc_xN$ thin films was affected will be shown as a function of pressure, plasma chemistry, RF bias, and ICP power based on X-ray diffraction, piezoresponse force microscopy and electrical measurements.

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[3] M. Reusch, et al., J. Vac. Sci. Technol. B, 34(5), 052001 (2016).

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