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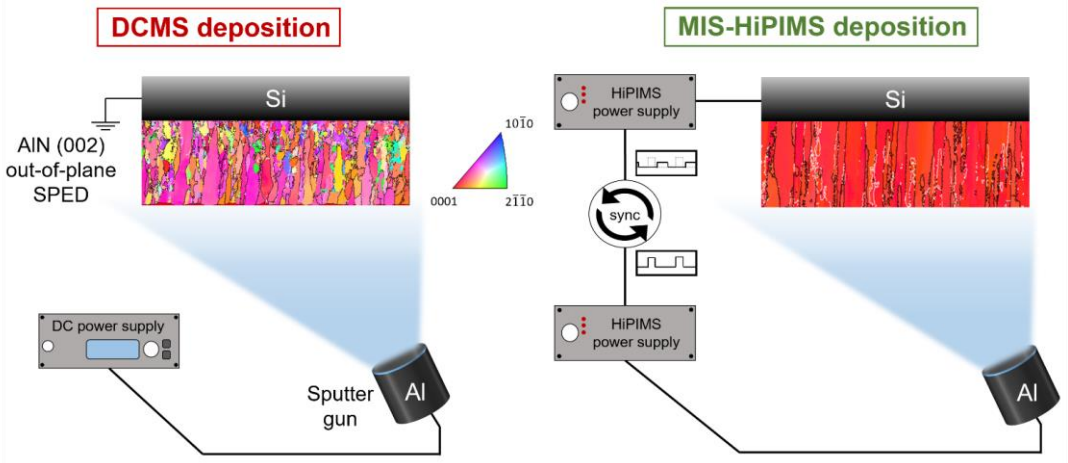
Improving the crystallinity and texture of oblique-angle-deposited AlN thin films using reactive synchronized HiPIMS

Many technologies, such as surface-acoustic-wave (SAW) resonators, sensors, and piezoelectric MEMS require highly-oriented and textured functional thin films. The most common synthesis approaches use either epitaxial stabilization or high deposition temperatures, whereas the best results are typically achieved for on-axis sputter geometries. In some scenarios, on-axis sputtering is not feasible, for instance, during co-deposition from multiple magnetrons or when coating structured substrates with high aspect ratios. Ionized physical vapor deposition (PVD) techniques, particularly high-power impulse magnetron sputtering (HiPIMS), provide ideal prerequisites for controlling the microstructure during growth, due to their high ionization rate. The ions can be accelerated onto the growing film using substrate-bias potentials to increase the ad-atom mobility. However, the increased amount of gas-ion incorporation in the films limits the feasibility of such synthesis approaches for the deposition of defect-sensitive functional thin films.

With newer developments in HiPIMS, it was found that the gas ions tend to arrive at the substrate earlier than the metal-ions, due to gas rarefaction and differences in atomic mass. Based on the information of the time-of-flight for the different ions, the substrate bias can be tailored accordingly to selectively accelerate the metal-ions onto the growing film. This reduces the process gas incorporation, and the related formation of point defects and increase in compressive stress. Therefore, metal-ion-synchronized HiPIMS (MIS-HiPIMS) provides a promising route for synthesizing functional thin films with tailored microstructure and texture.

In this work, we report on the oblique-angle deposition of highly textured, c-axis oriented AlN (0002) films, enabled by metal-ion synchronized HiPIMS. AlN thin films deposited using direct current magnetron sputtering (DCMS) and conventional HiPIMS are discussed for comparison. The effect of critical deposition parameters, such as the magnetic configuration, ion kinetic energies as well as substrate biasing are investigated. The films deposited using HiPIMS show a more pronounced texture and orientation compared to DCMS films. A Hiden **EQP 300** was used to measure the time of flight of the different ions. This allowed us to synchronize the substrate bias potential, to further improve the crystalline quality and texture of the films by reducing the Ar-ion incorporation. In addition to a pronounced out-of-plane texture, the films show uniform polarization making this synthesis route promising for piezoelectric applications.



AlN thin films deposited using reactive direct current magnetron sputtering (DCMS) under oblique angle deposition are characterized by random orientation of the grains and low crystallinity. With metal-ion synchronized HiPIMS (MIS-HiPIMS) both texture and crystallinity of the films can be improved significantly.

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