Aluminum Nitride Deposition via HiPIMS Without External Heating

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Subject Area
Photonics

Project Partner
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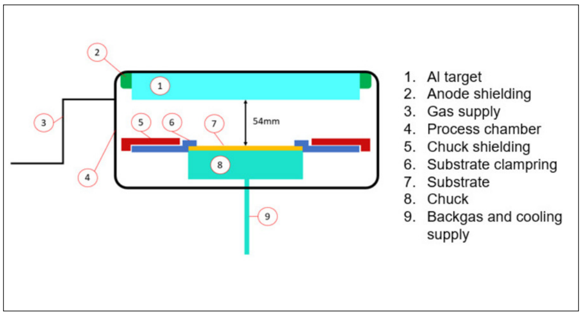
Introduction: Aluminum nitride (AlN) films have attracted attention due to their unique physical and chemical properties in a wide range of applications. In this study, crystalline aluminum nitride layers were deposited on 8-inch Si(001) and Si(111) substrates using reactive high-power impulse magnetron sputtering (HiPIMS) without external substrate heating. The deposition was performed with equipment (CLUSTERLINE®200) manufactured by Evatec. The films were characterized using X-ray diffraction (XRD), profilometry, scanning electron microscopy (SEM), and atomic force microscopy (AFM).

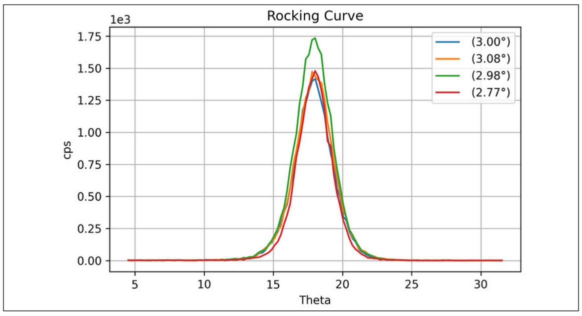
Result: The growth of crystalline AlN thin films was achieved after increasing the average deposition power. Following adjustments to the working pressure ratio, the full width at half maximum (FWHM) value of the rocking curve decreased from the initial crystalline results of 5.35° to 4.07°. The AlN layers already exhibited a mean roughness below 1nm within this process window. Subsequently, the influence of additional factors on the crystalline quality was considered at constant working pressure and compared with the literature. By using various gas mixtures of argon and nitrogen, as well as an exclusive nitrogen HiPIMS process, the FWHM value of the rocking curve was further reduced to 2.77°. Other research groups outside and within the company Evatec have grown AlN films using active substrate heating. For comparison, hot processes were also conducted, demonstrating an improved FWHM value of 2.03°. The influence of temperature on the crystalline layer is indeed present. In this study, the impact of the emitted heat from a HiPIMS plasma was observed. Finally, the significance of substrate crystal orientation and residual stress of the AlN film was addressed.

Conclusion: In summary, the deposition of crystalline and smooth AlN was achieved without active substrate heating. The temperature increase due to the energy flux from the highly ionized plasma contributes to an improved crystalline quality favoring HiPIMS deposition. The tradeoff respectivly the relationship between peak current shape, voltage, and nitrogen content was qualitatively demonstrated. The scope of this master's thesis only allowed for a focus on one particular working gas pressure. Nevertheless, good and promising results were obtained, indicating physical trends. The results obtained with 100% nitrogen flow were surprising, with the best FWHM values achieved for a layer thickness of 100nm and without substrate heating. The results for the heated processes are also interesting. They reflect the observation that the crystalline quality improves with different gas ratios. However, the exclusive nitrogen process behaves differently, performing worse at elevated temperature than when cold. Finally, the residual stress turned out to be relatively low. This reflects the detailed observations made by B. Belkerk, where the data from this master's thesis can be meaningfully integrated.

Cross-section of the utilized HiPIMS process module (CLUSTERLINE®200) showing the most important components.
Own presentment



The blue, orange, green, and red curves correspond to the gas ratios 3:2, 1:1, 2:3, and to 70 sccm N2 only.
Own presentment



HiPIMS process dependence on the nitrogen content with substrate heating (blue) and without external heating (orange).
Own presentment