Seeded Bulk AlN Growth by the Physical Vapor Transport Method

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Single-crystalline aluminum nitride (AlN) is a promising substrate material for AlGaN epilayers with high Al content, e.g. for solid-state deep-UV optoelectronics. The preferred method to grow AlN bulk single crystals is the physical vapor transport (PVT) method where solid AlN sublimates at temperatures well above 2000°C and re-condenses on an area with slightly lower temperature where a seed can be mounted.

While spontaneous nucleation yields crystals of highest structural perfection but limited size, single-crystalline diameter enlargement in conjunction with improvement (or at least, perpetuation) of crystal structural quality is only possible with homoepitaxial bulk growth on AlN seeds. In contrast, seeding on SiC seems especially promising to quickly reach AlN crystals of industrial relevant size and diameter. However, defects generated at the SiC/AlN interface lead to formation of grain boundaries and tilted domains. While AlN is still commercially available only in small quantities and sizes, both routes are actively researched. The current status and remaining challenges in growth technology will be reviewed.

Due to materials compatibility issues, the two routes are followed using different crucible materials and growth parameters. In this presentation, we will show in detail how the choice of growth strategy not only influences the available size and quality of the AlN crystals, but also the preferential growth direction (polarity) including the growth morphology (faceting), see Fig. 1, and the incorporation of impurities and intrinsic defects, see Fig. 2. The resulting differences have a decisive impact on deep-UV absorption and emission of bulk AlN. Thus, controlling contamination as well as faceting and orientation-dependent segregation effects will be a key prerequisite for further commercialization of AlN substrates.

[1] C. Hartmann, J. Wollweber, A. Dittmar, K. Irmscher, A. Kwasniewski, F. Langhans, T. Neugut, and M. Bickermann, *Jpn. J. Appl. Phys.* **52**, 08JA06 (2013).
[2] M. Bickermann, B.M. Epelbaum, O. Filip, B. Tautz, P. Heimann, and A. Winnacker, *Phys. Status Solidi C* **9**, 449 (2012).

a) 

b) 

Fig. 1: Bulk AlN single crystals grown on AlN seeds; a) grown in Al-polar direction in a pure tungsten set-up [1]; b) grown in N-polar direction in a carbon containing TaC-based set-up (cf. [2]). The as-grown surface is upwards.

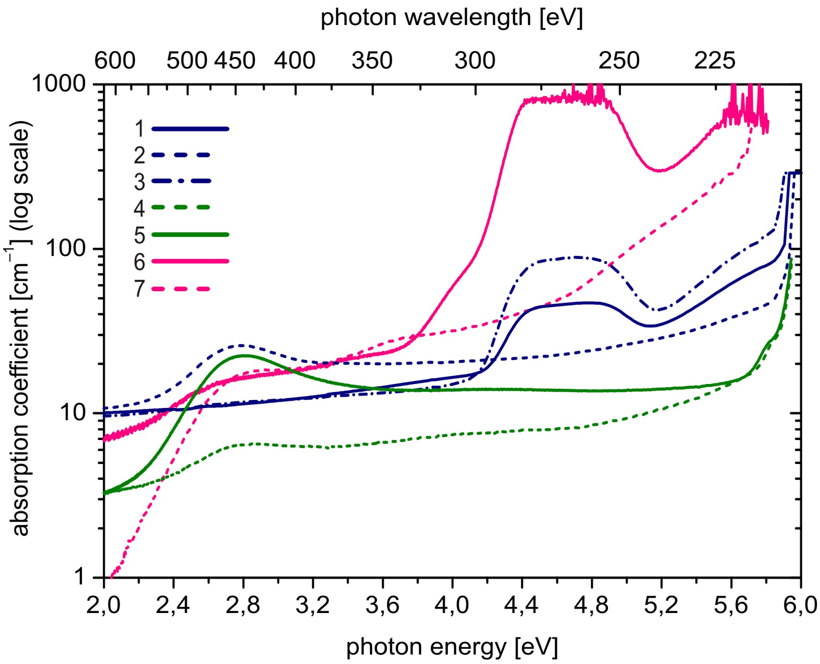

Fig. 2: Typical optical absorption spectra (logarithmic scale) of AlN bulk crystals grown in pure tungsten (samples 1–5) and TaC-based (samples 6–7) set-ups.