Bulk AlN Substrates for Deep-UV Optoelectronic Applications

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1. Introduction

Single-crystalline aluminium nitride (AlN) is the most promising substrate material for AlGaN epilayers with high Al content, e.g. for solid-state deep-UV optoelectronics and high-temperature power electronics, due to its excellent material properties, high thermal stability and chemical compatibility to AlGaN and GaN, and the possibility to grow compressively strained epilayers with a high critical thickness. This contribution reviews the current status and perspectives of bulk AlN substrates for epitaxy aiming at deep-UV optoelectronic devices.

2. Preparation and structural quality

AlN bulk single crystals are grown by the physical vapour transport (PVT) method at temperatures well above 2000°C. Crystals of high structural perfection can be grown using N-polar AlN single crystal wafers as seeds [1,2]. The structural quality of those crystals – and substrates cut from the crystals – is excellent, as evidenced by wet chemical etching, X-ray topography, and laser scattering tomography, with dislocation densities < 10^4 cm^{-2} and rocking curve FWHM values close to the instrument function (< 14 arcsec) [1]. Structural quality of first homoepitaxial results obtained by MOCVD (by FBH and TU Berlin) on such substrates will be presented.

3. Impurities and Deep-UV Transmission

Despite its high band-gap (6.1 eV), commercially available AlN substrates are generally not sufficiently transparent in the deep UV to warrant light out-coupling through the substrate backside. Optical absorption coefficients α at 265 nm wavelength (used for water disinfection and air purification) are typically above 100 cm^{-1} and are attributed to a optical transition induced by carbon from the growth environment [3].

Our group succeeded to control the incorporation of the main impurities during PVT growth, carbon, oxygen, and silicon, in a significant range by:

- adjusting the growth temperature (controlling crucible attack and reactions),
- using appropriate hot-zone materials (tungsten acts as carbon getter, TaC and graphite form volatile CO and thus lead to lower oxygen incorporation in the crystals),
- tailoring the starting material purity by appropriate pre-processing (sintering), and
- intentional doping (of silicon).

We will show that using these approaches, deep-UV transparent AlN single crystals with α(265 nm) as low as 14 cm^{-1} can be prepared even when growing in the N-polar growth direction in TaC crucibles when the total concentration of impurities stays below 10^{19} cm^{-3} and 3 [C] < ([O] + [Si]). Such crystals are enough transparent for reasonable deep-UV light out-coupling even without substrate back-thinning or HVPE layer growth [4].

References

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