Influence of Seed Orientation on Structural and Optical Properties of Homoepitaxial Grown Bulk AlN Single Crystals

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AlN is the most promising substrate candidate for high quality AlGaN structures with Al concentrations > 40 % at, e.g. for deep-UV optoelectronic applications. Contrary to the great commercial expectations, basic understanding of the AlN bulk growth behavior is still only little developed.

The most accepted growth technique for high quality AlN single crystals is Physical Vapor Transport (PVT). Growth is typically performed on basal (0001) or (000-1) surfaces. Previous studies on freestanding grown AlN single crystals by PVT revealed strong differences of impurity incorporation and, as a result, of optical and structural properties in the volume parts (growth zones) that formed due to growth on different facets [1,2]. In particular, this holds for the application relevant deep-UV transparency which presumably depends on the carbon impurity content and the oxygen/carbon ratio [3]. One research direction is thus to evaluate the growth direction dependent spatial dimensions of growth zones and their differences in properties in order to provide AlN substrates having large areas of homogeneous characteristics.

In this contribution, detailed investigations of the directional growth morphology as well as structural and optical properties will be presented. The study is based on homoepitaxial AlN bulk growth using seeds of very high structural perfection (rocking curve FWHM about 15 arcsec, mean EPD << 10^4 cm^{-2}) in different orientations: Basal plane (0001) and (000-1), prismatic (10-10), and rhombohedral (10-11), (10-14), (10-1-1), and (10-1-4). Growth is performed in a set-up based on TaC ceramic crucibles and carbon fiber insulation at temperatures of about 2100°C. The crystals are allowed to grow free-standing due to proper tailoring of the thermal field inside the growth zone.

The crystals are completely faceted regardless of growth orientation. The structural perfection and morphology of the surfaces is evaluated by X-ray techniques and atomic force microscopy. The growth zones are characterized in terms of growth rate, impurity concentrations, optical transparency, defect density, and charge carrier concentration by microscopy, secondary ion mass spectrometry (SIMS), UV-VIS spectrometry, wet chemical etching, and temperature dependent optical transmission imaging, respectively.

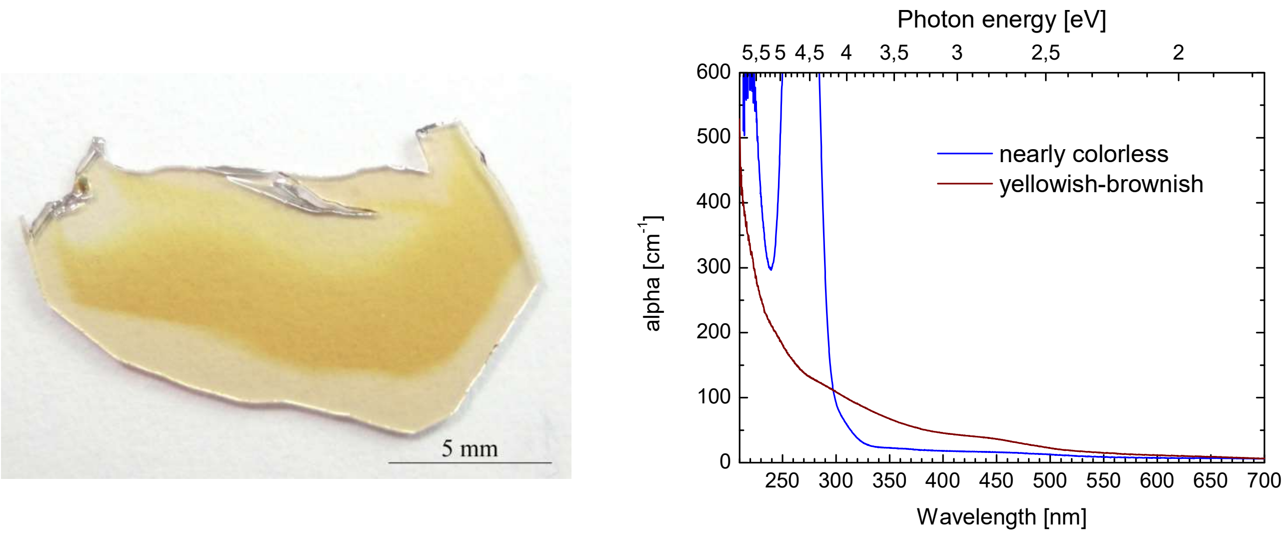
[1] C. Hartmann, J. Wollweber, A. Dittmar, K. Irmscher, A. Kwasniewski, F. Langhans, T. Neugut, M. Bickermann, IWN 2012 oral presentation, accepted manuscript for Jpn. J. Appl. Phys. (2013).

[2] M. Bickermann, P. Heimann, B. M. Epelbaum, Phys. Status Solidi C **3** (2006) 1902-1906.

[3] M. Bickermann, B. M. Epelbaum, O. Filip, B. Tautz, P. Heimann, A. Winnacker, Phys. Status Solidi C **9** (2012) 449-452.

Abstract extension

Fig. 1: AlN single crystals grown on
N-polar (000-1) AlN wafer



(a) (b)

Fig. 2: a) double side polished {0001}-oriented AlN wafer with pronounced zonar structure;
b) absorption spectra of yellowish and nearly colorless regions on the wafer

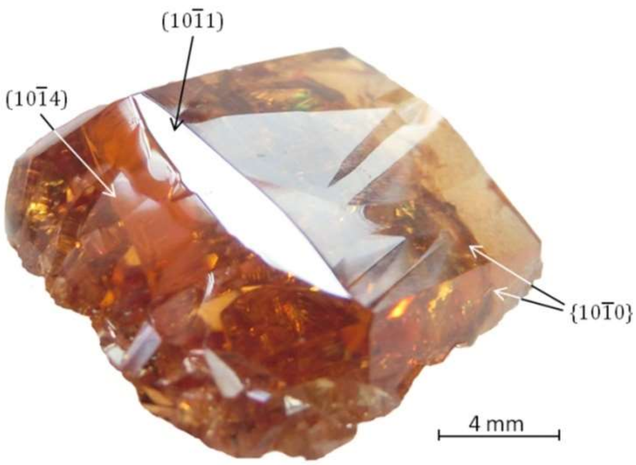


Fig. 3: AlN single crystals grown on (10-11) AlN wafer

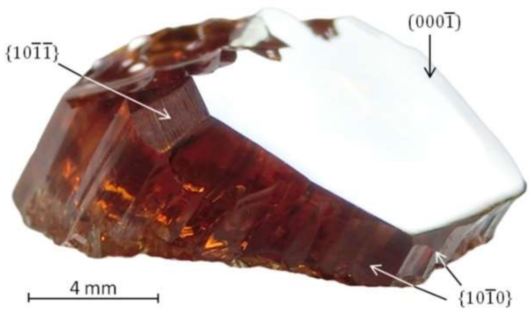


Fig. 4: AlN single crystals grown on (10-1-4) AlN wafer