Structural Defects in Aluminum Nitride Bulk Crystals Visualized by Cathodoluminescence Maps

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Structural defects presumably decorated by impurities and intrinsic point defects act as preferred luminescent recombination centers in AlN [1]. Therefore, they are visible in panchromatic cathodoluminescence (CL) maps obtained on a scanning electron microscope (SEM), while CL spectra taken at different sample locations yield information about involved defects. In the presentation, we will discuss advantages and limitations of the technique as well as defect evolution in AlN bulk crystal growth in detail.

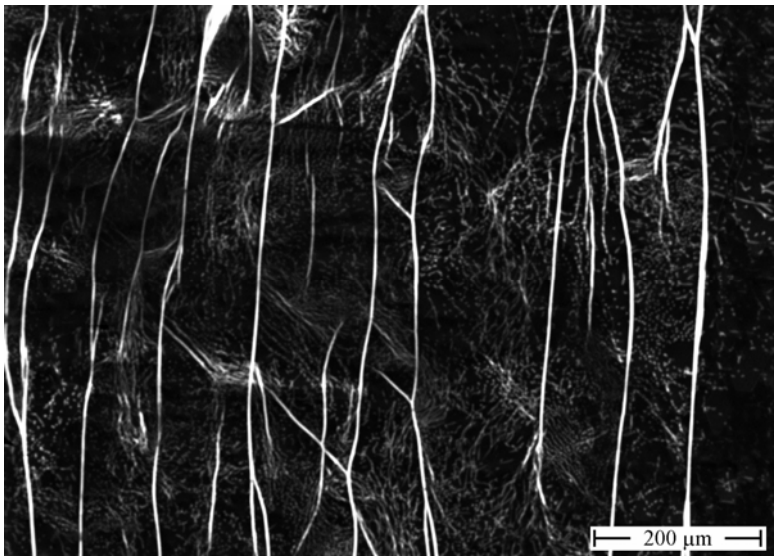

Fig. 1: Panchromatic cathodoluminescence map of a wafer cut perpendicular to the growth direction. Bright lines indicate LAGBs, points indicate single dislocations.

First, we show that indeed bright areas (dots and lines) in CL maps will form pits and grooves after wet chemical defect selective etching. CL maps can thus be reliably used to investigate the evolution of dislocations, low-angle grain boundaries (LAGB), and traces of traveling hollow defects, see Fig. 1. Even local charging effects of the wafer surface in the SEM may be used to trace dislocations and LAGBs by their enhanced carrier recombination. Using these techniques, structural defects and their evolution in a representative AlN bulk single crystal of 30 mm diameter and 15 mm height is investigated by evaluating series of wafers cut in different crystallographic directions.

Many structural defects are generated at the initial growth interface, but most of them disappear within the first 300 µm of growth. However, rows of dislocations forming LAGBs emanate from the seed and extend through the crystal parallel to the (0001) axis. Their density perpendicular to (0001) varies locally between 10^2 cm^{-2} and 10^4 cm^{-2}. Dissolution of LAGBs into dislocations is regularly observed but does not lead to a substantial change in density. Dislocation density in the areas between LAGBs is in the 10^4 cm^{-2} range. As hollow defects travel through the crystal by 'negative crystal growth', recrystallized areas with different CL background intensity due to impurity segregation as well as micropipe-like defect traces are observed, similar to features observed in SiC [2]. Finally, the defect density in the side areas which are formed due to diameter expansion is investigated, taking into account local changes in background CL intensity due to formation of side facets (zonar structure, cf. [3]).

[1] A.Y. Polyakov et al., Physica B 404 (2009) 4939–4941.
[2] T.H. Kuhr et al., J. Appl. Phys. 89 (2001) 4625–4630.
[3] M. Bickermann et al., phys. stat. sol. (c) 3 (2006) 1902-1906.