Methodology of line dislocation density mapping in aluminum bulk crystals using high energy X-ray transmission topography for quality control in crystal growth

R. Weingärtner[1]*, S. Besendörfer[1] A. Lesnik[1] M. Weisser[2] and E. Meissner[1,3]
*Roland Weingärtner: roland.weingaertner@iisb.fraunhofer.de
1 Fraunhofer Institute for Integrated Systems and Device Technology IISB, Department Materials, Schottkystrasse 10, Erlangen, 91058, Germany
2 Institute for Crystallography and Structural Physics ICSP, Friedrich-Alexander-Universität Erlangen-Nürnberg, Staudtstrasse 3, Erlangen, 91058, Germany
3 Chair of Electron Devices, Friedrich-Alexander-Universität Erlangen-Nürnberg, Cauerstrasse 6, Erlangen, 91058, Germany

AlN bulk crystals of approximately 5 mm height were grown by physical vapor transport method. The growth takes place on the N-polar face of the seed [1, 2]. We select the seeds from appropriate bulk crystals for several growth generations such that the respective threading dislocation density offered by each seed is minimal. Line dislocation density determination of the bulk crystal and careful seed selection is essential to the successful growth of more generations of crystals without degrading the high structural quality.
As a main result, we show that high energy X-ray transmission topography serves as a key tool for complete bulk crystal inspection and qualification and detailed evaluation of its dislocations. We use a high energy X-ray tool available at ICSP [3, 4], equipped with a tungsten anode in standard Laue transmission geometry which was operated at 180 kV and 2.75 mA. With this setting we ensure to traverse a complete crystal of approximately 40 mm in diameter, horizontally along the *c*-plane.
We performed diffraction measurement at the *m*- and *c*-plane of the bulk crystal using the continuous part of the X-ray spectra at diffraction angles in the range from 3° to 5°.
We present methodologies and results for two measurement modes which can be addressed with this setup: First, rocking curve mapping over the whole crystal volume, determined in focused Laue geometry which represent density and internal stress maps of the complete crystal. Second, measurements in defocused Laue geometry generating integrated topograph images of dislocations in the crystal volume.
It can be shown that mean density of dislocations is below 1000 cm^{-1} in most of our crystals. The distribution of dislocation lines inside the boules of the investigated aluminum nitride single crystals can be visualized. We are able to trace the defect propagation of the TDs from the seed towards the bulk growth surface in detail. Although the method is demonstrated for boules of an average 40 mm in diameter and 5 mm height, we see no obstacles to investigate crystals of even larger diameters.
Conclusively, beside the structural investigation for the fundamental understanding of the growth process, we propose this method also as featured application for separating out a failed boule in a production line before proceeding with the wafering process.

References

[1] B. M. Epelbaum, C. Seitz, A. Magerl, M. Bickermann, A. Winnacker, J. Crystal Growth 265, 577 (2004)
[2] T. Wicht, S. Müller, R. Weingärtner, B. Epelbaum, S. Besendörfer, U. Bläß, M. Weisser, T. Unruh, E. Meissner, J. Appl. Cryst., 53, 1080 (2020)
[3] C. Bergmann, J. Will, A. Gröschel, M. Weisser, A. Magerl, Phys. Status Solidi A, 1 (2014)
[4] M. Stockmeier, A. Magerl, J. Appl. Cryst. 41, 754 (2008)