Revealing Growth Discontinuities in Ammonothermal GaN by Advanced Bragg Diffraction Imaging Techniques

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Ammonothermal growth is a key technique for producing high-quality GaN substrates with low dislocation densities, yet repeated regrowth steps during seed enlargement and bulk crystal fabrication inevitably introduce growth discontinuities and associated defects [1]. In this work, we investigate such defect structures in ammonothermal GaN using complementary Bragg diffraction imaging techniques, namely laboratory Lang X-ray topography (L-XRT) and synchrotron-based rocking curve imaging (RCI).

Growth discontinuities manifest predominantly as chains of dislocation bundles forming along specific crystallographic facets, as well as tiling seams originating from seed coalescence. These features appear as extended contrast lines in L-XRT topographs and can be chronologically linked to individual regrowth steps. Quantitative RCI analysis reveals that these defect regions are associated with local lattice tilts of up to ~13 arcsec and alternating strain fields on the order of ±3 arcsec.

A central result of this study is that, despite the presence of such pronounced defect structures, dynamic diffraction effects can still be clearly observed [2]. This is attributed to the remarkably high structural quality of the GaN crystal in the immediate vicinity of the defects. Regions adjacent to dislocation bundle chains exhibit ultra-low dislocation densities and minimal lattice distortion, providing sufficiently perfect volumes for the formation of coherent wavefields required for dynamical diffraction. As a consequence, the diffraction contrast cannot be interpreted solely within a kinematical framework but requires consideration of dynamical scattering processes. These findings highlight the coexistence of localized defect-induced lattice perturbations and extended regions of outstanding crystalline perfection within ammonothermal GaN substrates. The results further demonstrate that Bragg diffraction imaging is highly sensitive not only to defect structures but also to subtle variations in crystal quality that govern the transition between kinematical and dynamical diffraction regimes. In addition to lateral growth discontinuities, vertical discontinuities along the growth direction are considered to provide a comprehensive understanding of defect formation mechanisms in ammonothermal GaN.

This work contributes to the optimization of crystal growth processes by linking specific growth conditions to defect formation while simultaneously emphasizing the preservation of excellent crystal quality necessary for advanced device applications.

References

[1] T. Sochacki, et al., Growth of bulk GaN crystals for the production of substrates, in Comprehensive Semiconductor Science and Technology, second edition, Elsevier, 2025.
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