Evolution of dislocations throughout the seeded growth of AlN crystals investigated by 3D X-ray diffraction imaging.

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Presentation type: Oral **Presentation time:** 12:00-12:15

Aluminum nitride (AlN) is a critical substrate material for deep ultraviolet optoelectronics, high-power electronics, and sensor applications. Next to challenges related to n-type doping of AlN, the lack of high-quality crystals with diameter of 4 inches or more is currently hindering a widespread exploitation of this material in semiconductor industry. In the development of crystals with larger diameters and volume, maintaining a sufficient supply of source material and low thermal gradients becomes increasingly challenging. However, controlling these parameters is crucial to limit the formation of crystal defects, such as grain boundaries and dislocations, thereby preserving high crystal quality.

Our work aims at understanding the evolution of defects, in particularly dislocations, during seeded growth of AlN crystals and their diameter-increase by growth on different crystallographic surfaces. We investigated the behavior of dislocations during regrowth on the seed using 2D and 3D X-ray diffraction imaging and complementary techniques, enabling us to determine the direction and sense of the Burgers vectors, as well as dislocation line trajectories in 3D.

While parts of the dislocations are inherited from the seed, they typically exhibit a strong lateral displacement at the seed to bulk interface.

In crystals grown at a relatively small lateral temperature gradient, dislocations bend near the seed interface, with their movement governed by a climb process. The absence of slip was inferred from the Burgers vector orientation in relation to the movement direction and can be explained by a low resolved shear stress that is insufficient to activate glide. In contrast, the climb process is facilitated by a significant level of oxygen impurities, and becomes the dominating mechanism of motion during growth at low temperature gradients (0.1K/mm) [1].

When growing at larger temperature gradients, the crystals diameter increases rapidly [2], entailing enhanced nucleation of dislocations at the ⟨1-100⟩ corners that glide towards the center of the crystal [3]. Dislocations from the seed, however, are partially deflected at the regrowth interface and cannot penetrate into the bulk as shown by 3D imaging data.

These findings demonstrate how the temperature field can be used to control defect formation in AlN substrates and how 3D X-ray diffraction imaging enables insights into the history of dislocation formation, which can be related to the growth processes in these crystals.

References

[1] Straubinger, T. et al. (2023), Crystal Growth & Design, 23(3), pp. 1538–1546.
[2] Hartmann, C. et al. (2023), Applied Physics Express, 16(7), p. 075502.
[3] Herms, M. et al. (2025), physica status solidi (a), 222(19), p. 2400787.