From High-Pressure Physics to Full-Stack GaN

Building a Technology from Crystal to Device

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Gallium nitride has evolved from a fundamental materials-physics challenge into one of the key semiconductor platforms for power electronics, optoelectronics and emerging quantum technologies. This evolution requires much more than an efficient crystal-growth method. Device performance ultimately reflects the entire history of the material – from bulk crystallization through wafer preparation and epitaxy to processing and device fabrication.

This evolution will be presented from the perspective of research carried out at the Institute of High Pressure Physics of the Polish Academy of Sciences, Unipress. The story begins with the thermodynamic constraints governing GaN stability and early high-pressure solution-growth experiments. It then turns to the implementation and further scaling of ammonothermal crystallization at Unipress, and to the challenges of producing large-area native GaN substrates with controlled defect, impurity and stress distributions.

The central theme is the coupling between successive stages of the technology. Wafer preparation modifies the near-surface defect structure; polarity, miscut and surface condition affect epitaxial growth; substrate defects and impurities influence the electrical and optical performance of devices; and ion implantation combined with ultra-high-pressure annealing provides additional routes for selective doping and functionalization. Examples from power devices and optoelectronic structures illustrate how device performance can serve as a sensitive probe of the complete materials history.

Finally, I will show how recent infrastructure and research programs at Unipress are integrating these capabilities into a full-stack GaN platform – connecting crystal growth, substrates, epitaxy, processing, metrology and devices, and creating a basis for pilot-line activities and future industrialization.

The central message is simple: GaN is no longer merely a crystal-growth problem. Progress increasingly depends on controlling not only each stage from crystal to device, but also the interfaces between them.