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Hydride Vapor Phase Epitaxy Reactor for Bulk GaN Substrate Manufacturing

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Abstract

An HVPE reactor for the growth of bulk GaN crystals with a diameter of 50 mm was developed. High-capacity external halide precursor sources for gallium, aluminum, and boron allowed for non-stop growth of the bulk GaN layers with a thickness of 10 mm and higher. Thin layers of AlN, AlGaN, and BN can be deposited in the same process with bulk GaN growth. A load-lock vacuum chamber and a dry in-situ growth chamber cleaning were implemented to improve the growth process reproducibility. Freestanding GaN crystals with a thickness of 5 mm and a diameter of 50 mm were grown with the reactor.

1. Introduction

Bulk gallium nitride substrates are necessary for growing device structures that require high crystalline quality of epitaxial layers - blue and green lasers, high power LEDs, vertical power devices. The main methods for bulk GaN growth are hydride vapor-phase epitaxy (HVPE) and solution growth by the ammonothermal method and the Na-Flux method. The HVPE method allows to grow high purity epitaxial layers, including uncompensated semi-insulating [1], the structural quality of such layers is determined by the quality of the seed substrate: the dislocation density in the HVPE epitaxial layers grown on a bulk GaN substrate does not exceed the dislocation density in the substrate. The HVPE method is also promising for high pure device-quality layer growth [1]. Since the first work on HVPE GaN growth by Tietjen and Maruska [2], a boat with molten gallium, placed inside the reactor near the growth zone is typically used as a source of gallium chloride. This limits the gallium source capacity and complicates the design of the reactor with multiple metal sources. Most of HVPE reactors described in the literature contain quartz parts, that is a source of silicon and oxygen contamination [1, 3]

2. HVPE reactor design

This work presents a reactor with high capacity external metal chloride sources and quartz-free growth chamber, designed for bulk GaN layers production (fig. 1a). The reaction

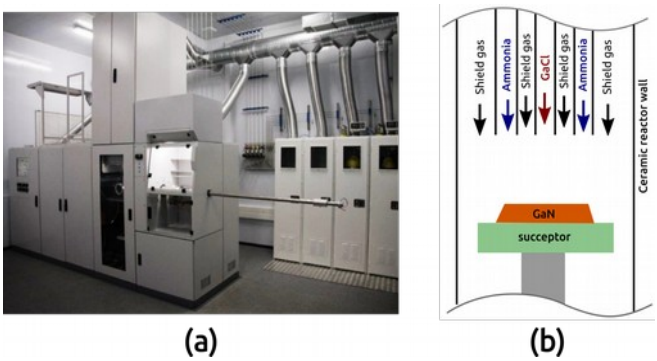

Figure 1: (a) Photograph of the HVPE reactor. (b) Schematic drawing of the reactor growth chamber (not in scale)

chamber (fig. 1b) is vertical with hot walls and external resistive heating that provides growth temperature up to 1200 C. All components of the growth chamber are made of non-oxide ceramics and refractory metals. The substrate with a diameter of 50 mm is placed horizontally, growth surface up. During the growth process, the substrate rotates at a rate of 100 rpm. The gas injector consists of a set of coaxial tubes. Nitrogen is used as a carrier gas. Gallium chloride is fed through the inner tube. Inert gas shielding between the ammonia supply line and the gallium supply line completely prevented parasitic growth on the injector nozzle and allowed to grow GaN films with thickness up to 5 mm in a single process. Careful optimization of gas flow allowed to suppress convection (fig. 2) and to achieve a film thickness uniformity of 5% at a growth rate of 200 um/h (fig. 3).
Gallium and aluminum precursors are stored in high-capacity sources located outside the reactor and are delivered to the reaction chamber through heated pipelines in the form of volatile trichlorides (fig. 4).
A vacuum load lock is used to load and unload the substrate which shortens the reload time and prevents reactor contamination by the atmosphere. Gas phase dry etching procedure was developed to clean the growth chamber walls and the substrate holder between the growth processes, without shutting down the reactor, which made it possible to improve reproducibility and increase the service life of the

growth chamber elements.

Bulk GaN crystal with a thickness of 2.8 mm, grown on a sapphire substrate at a deposition rate of 200 um/h using the two-stage growth process [4], is shown in fig. 5a. The (0002) X-Ray rocking curve full width at half maximum was 51 arcsec. Threading dislocation density estimated by cathodoluminescent microscopy by measuring dark spot density was 2×10^{6} cm $^{-2}$ (fig. 5b).

3. Conclusions

An HVPE reactor with a quartz-free growth chamber, a vacuum load lock and external precursor sources was developed. Bulk GaN films with thicknesses of up to 5 mm were grown with the reactor.

References

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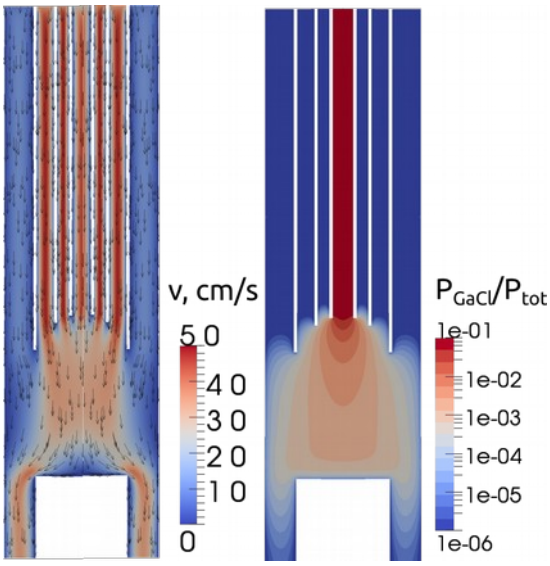

Figure 2: CFD simulation of the growth chamber: velocity distribution (left), Gallium Chloride partial pressure (right)

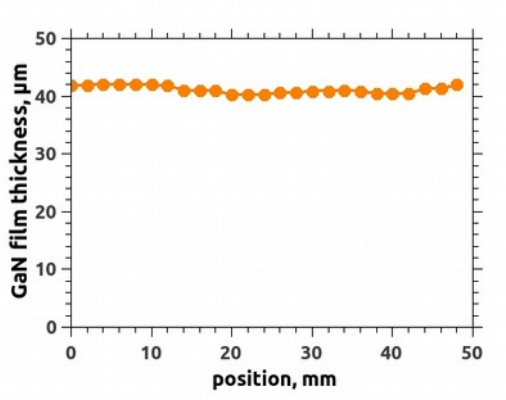

Figure 3: The thickness profile of the GaN film deposited at a growth rate of 200 µm/h, the thickness inhomogeneity is less than 5%.

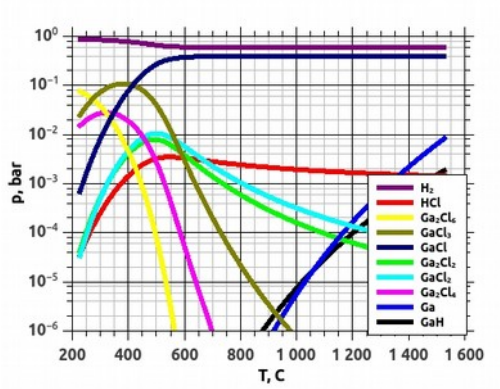

Figure 4: Equilibrium gallium chlorination products: thermodynamic calculation

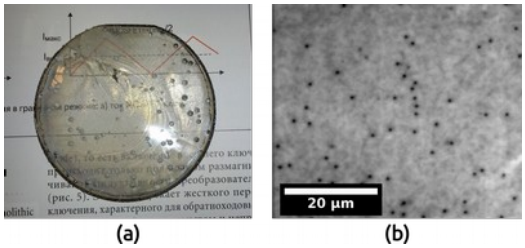

Figure 5: (a) Freestanding GaN crystal with a thickness of 2.8 mm. (b) Cathodoluminescent micrograph of the 2.8 mm thick GaN crystal. Threading dislocation density is 2×10^{6} cm $^{-2}$