Hydride Vapor Phase Epitaxy (HVPE) growth method

HVPE method is based on the crystallization from the vapor phase. Crystallization of gallium nitride is a result of the reaction between gallium chloride and ammonia at high temperature (1045°C) and pressure below 1atm.

HVPE is generally based on crystallization on a foreign material, mainly GaAs or sapphire. Etching or self lift-off techniques are used to remove the GaN crystals from the foreign substrates.

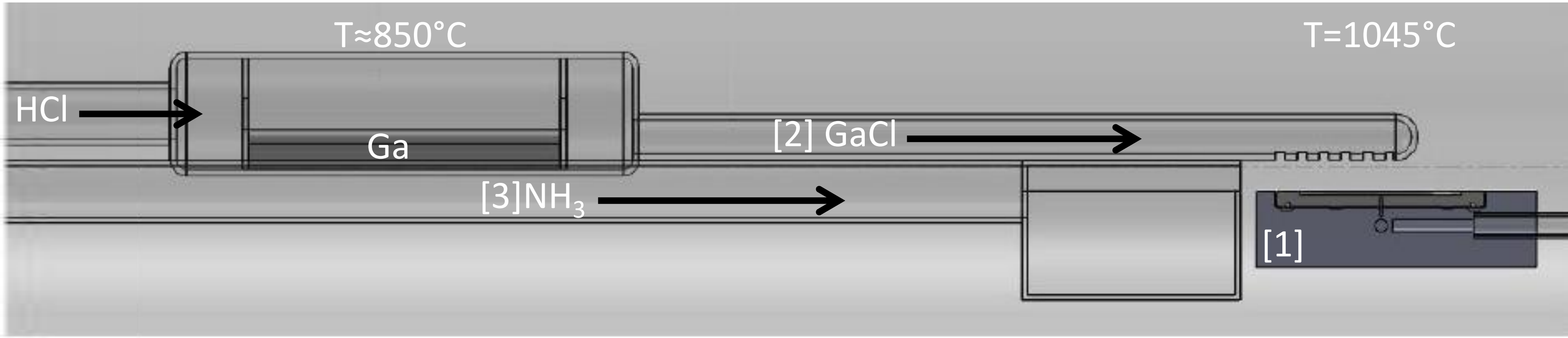
Main advantages of this technique are relatively fast growth rate (up to 500µm/h) and high purity of the obtained material.

Method and experimental setup

Two main reactions:

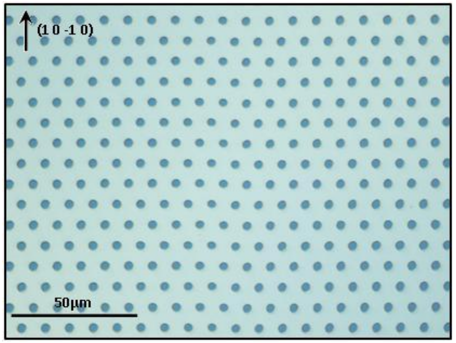
GaCl synthesis: $2HCl + 2Ga \rightarrow 2GaCl + H_2$

GaN synthesis: $GaCl + NH_3 \rightarrow GaN + HCl + H_2$

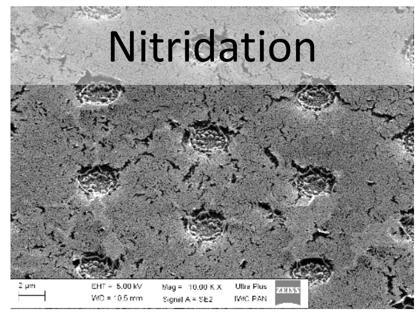


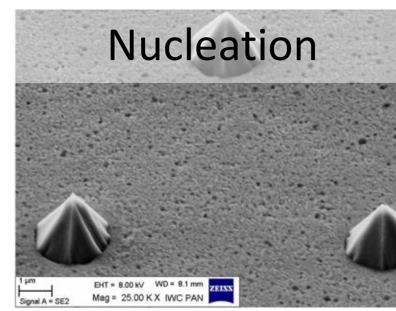
Schematic view of the HVPE reactor used the NL3 laboratory. It is a home-built horizontal quartz reactor with a rotating quartz susceptor [1]. GaCl is supplied vertically over the surface of the susceptor using of shower head-type quartz nozzles [2]. NH3 is supplied [3] by a quartz nozzle located on the level of the susceptor. For the main HVPE crystallization growth the temperature of 1045°C is applied and for the GaCl synthesis that of about 850°C.

Heteroepitaxial growth



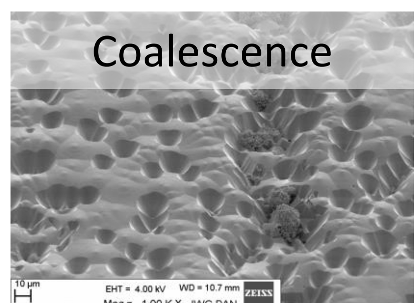
2-inch MOCVD-GaN/sapphire templates with photo-litographically patterned Ti mask are used as substrates. Thickness of the MOCVD-GaN layer is 500nm. The Ti mask has openings of 3μm in diameter with a distance of 9μm between the openings.





Stages of HVPE process:

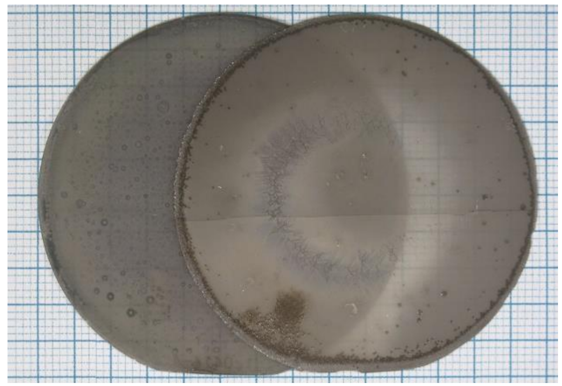
- Heating to growth temperature
- Nitridation
- Nucleation
- Coalescence
- Main growth
- Cooling down



Heteroepitaxial growth

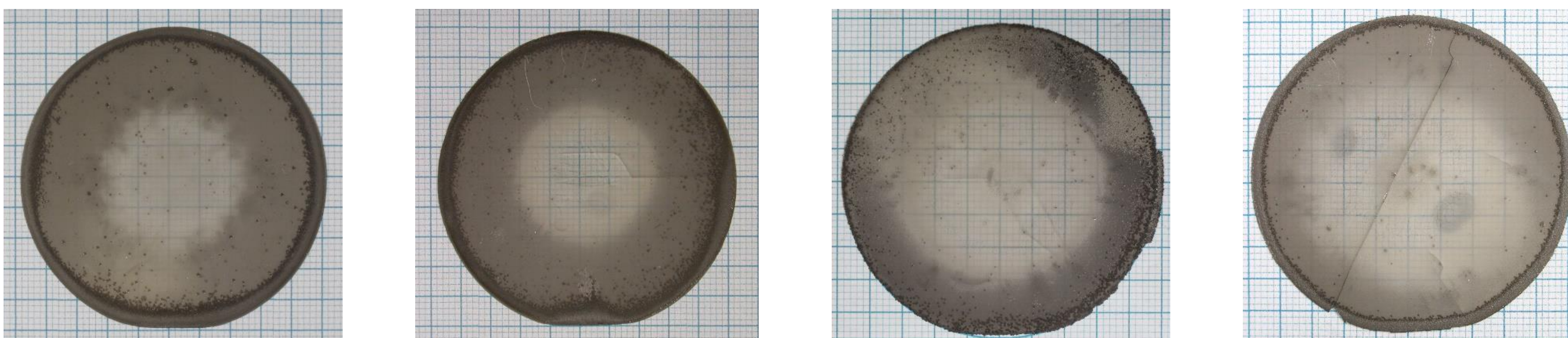
Self lift-off technique is applied to remove HVPE-GaN crystals from MOCVD-GaN/sapphire templates.

GaN on sapphire



Sapphire and GaN crystal

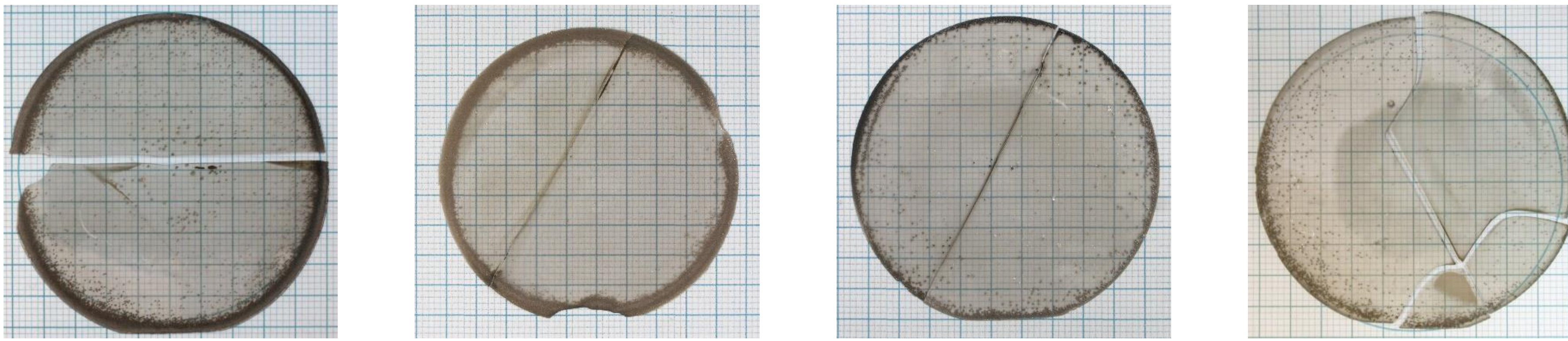
GaN crystal



GaN crystals after self lift-off

Heteroepitaxial growth

Mismatch between lattice constants and thermal expansion coefficients of sapphire and the new grown GaN crystal leads to a strong strain. This strain may lead to cracks…



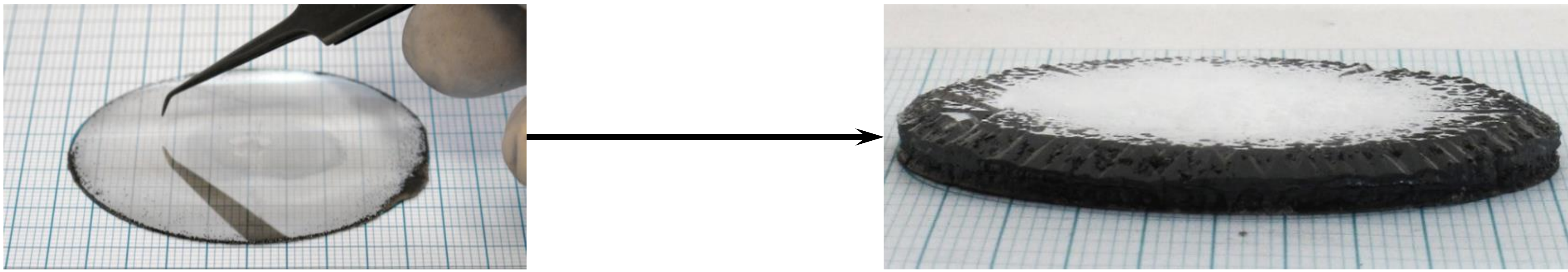
…and poor quality of obtained crystals:

- Large curvature (R≈5m)
- High density of dislocations (TDD ~ $10^6 – 10^7$ cm^{-2})

A solution to the appearance of strain in the HVPE grown material can be homoepitaxial growth.

Homoepitaxial growth

Growth on Free-Standing HVPE-GaN seeds



Advantages:

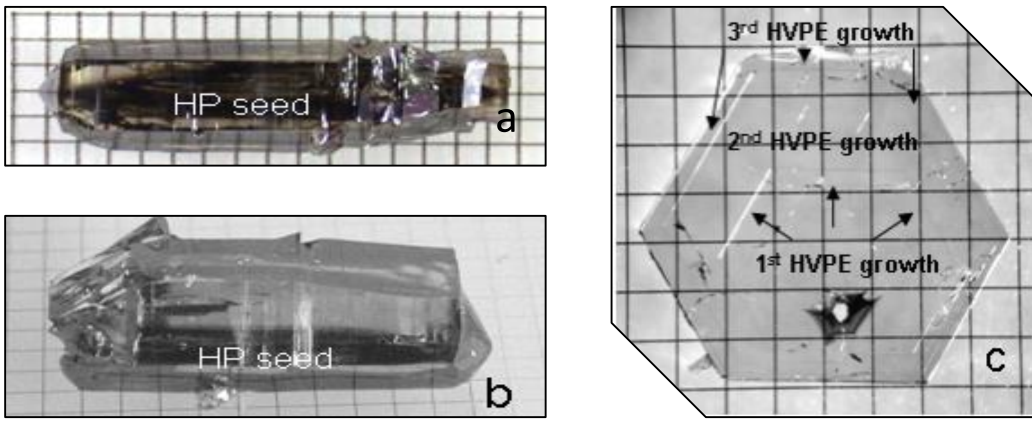
- Large size of the seeds

Disadvantages:

- Growth on substrates of poor structural quality → low structural quality of the obtained crystals
- Impossible to significantly improve the quality of the new grown crystals

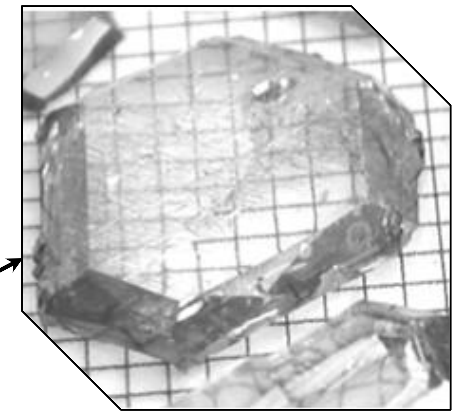
Homoepitaxial growth

Growth on HNPS-GaN seeds



on a HNPS needle

on a HNPS platelet



Advantages:

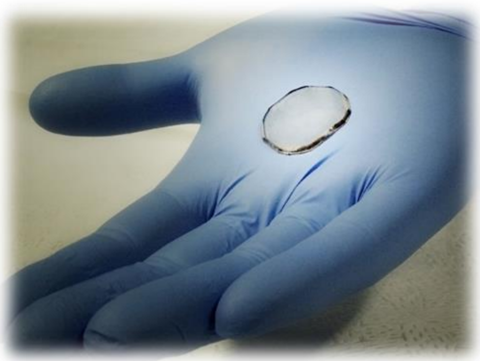
- Growth on substrates of high structural quality → high structural quality of the obtained crystals

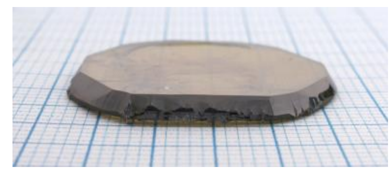
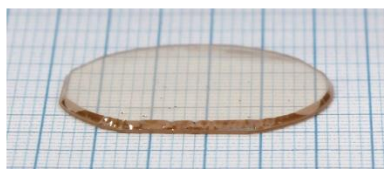
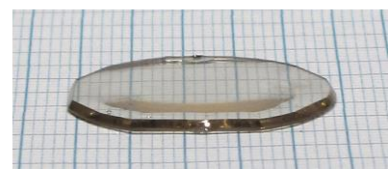
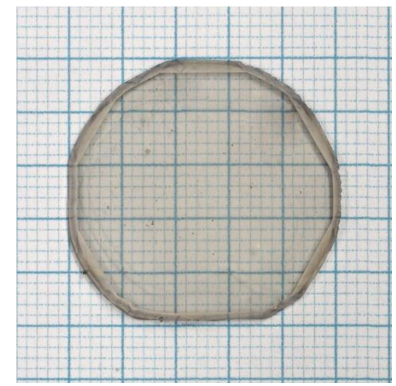
Disadvantages:

- Very small size of the seeds
- Impossible to significantly improve the size of the new grown crystals

Homoepitaxial growth

Growth on ammonothermal-GaN
seeds



Advantages:

- Growth on substrates of high structural quality → high structural quality of the obtained crystals
- Large size of the seeds (up to 2”)