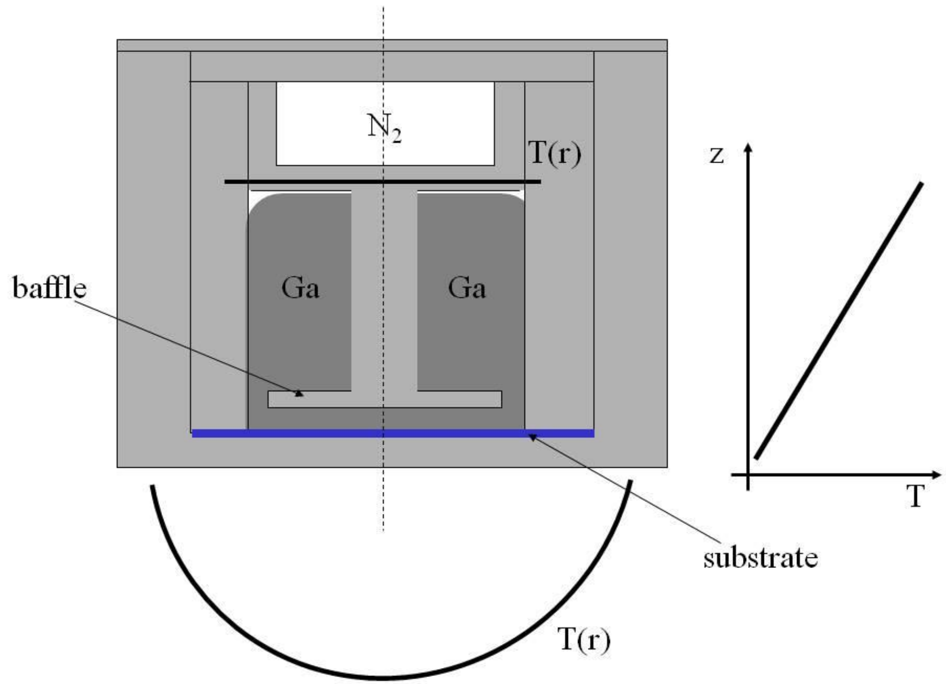
# High Nitrogen Pressure Solution (HNPS) growth method

## Seeded Growth
## LPE Growth – Single Seed Configuration

**The deposition of GaN takes place on a substrate, in order to force the growth in a particular direction. Few kinds of substrates, i.e.: HNPS-GaN, HVPE-GaN, SiC, sapphire, and sapphire/GaN MOCVD templates, were used.**

**A crucible with a baffle plate positioned close to the seed, axial and radial temperature distributions.**



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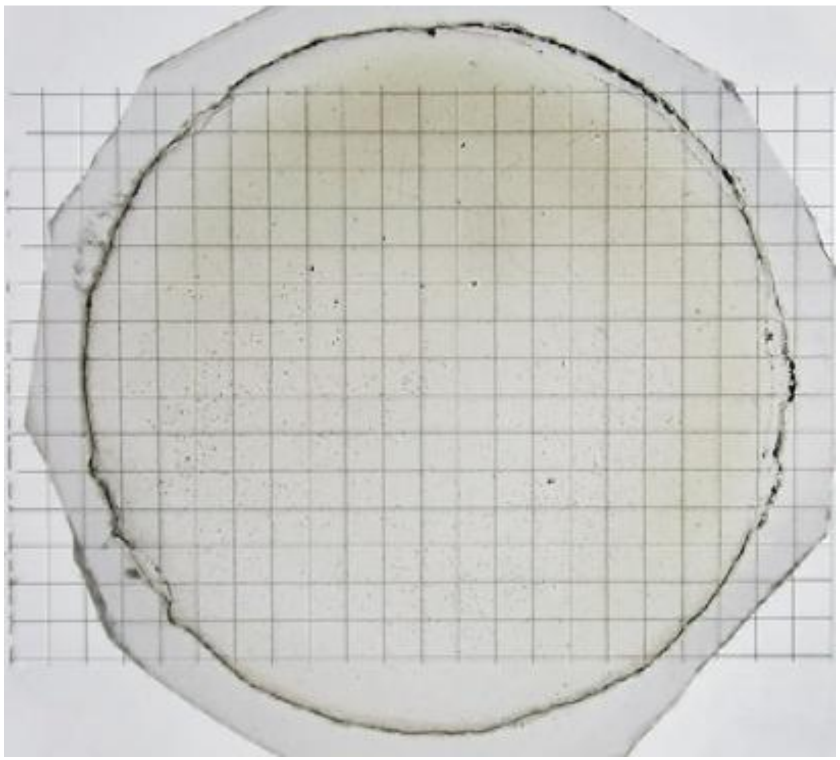
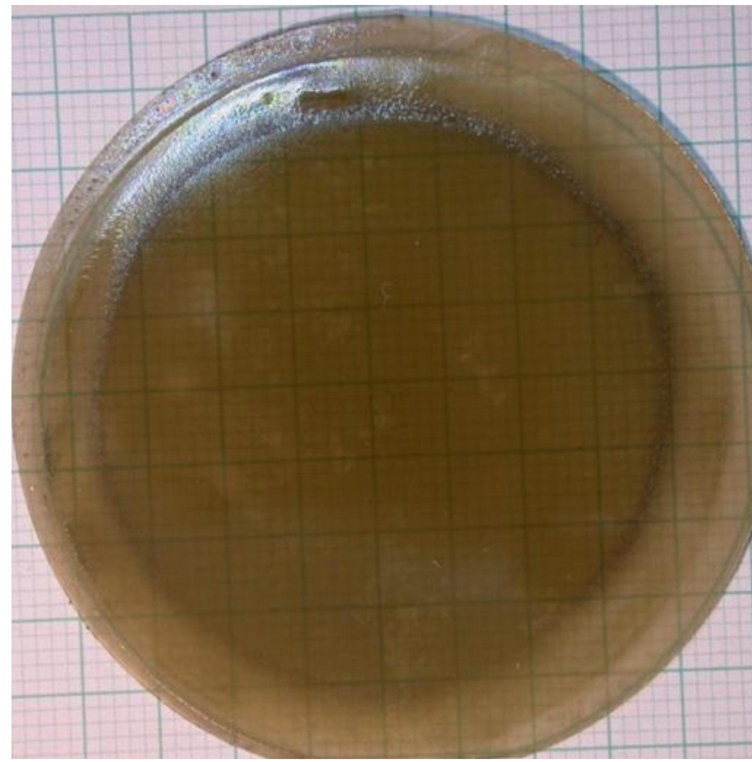
**The baffle plate allows to obtain a flat (macroscopically) crystallization front on the substrate and consequently to maintain a flat GaN surface during a long crystallization run.**



**GaN grown on a MOCVD-GaN/sapphire template**



**GaN grown on a free standing HVPE-GaN**

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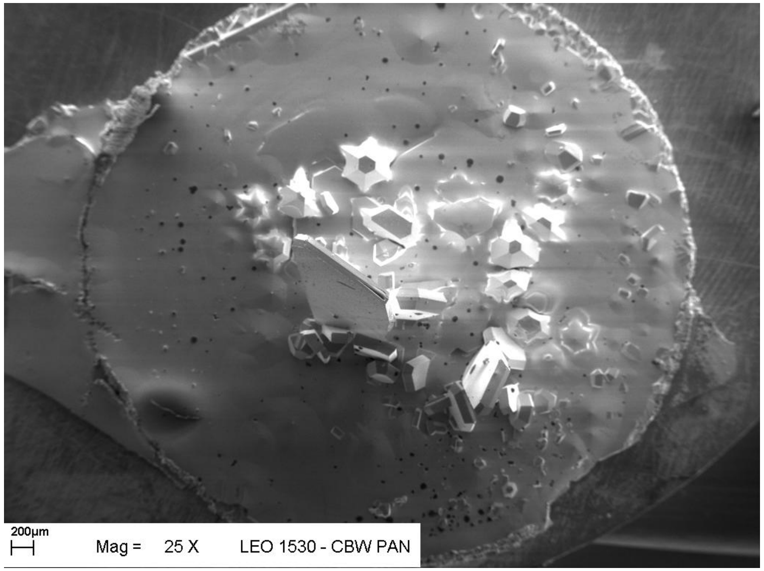
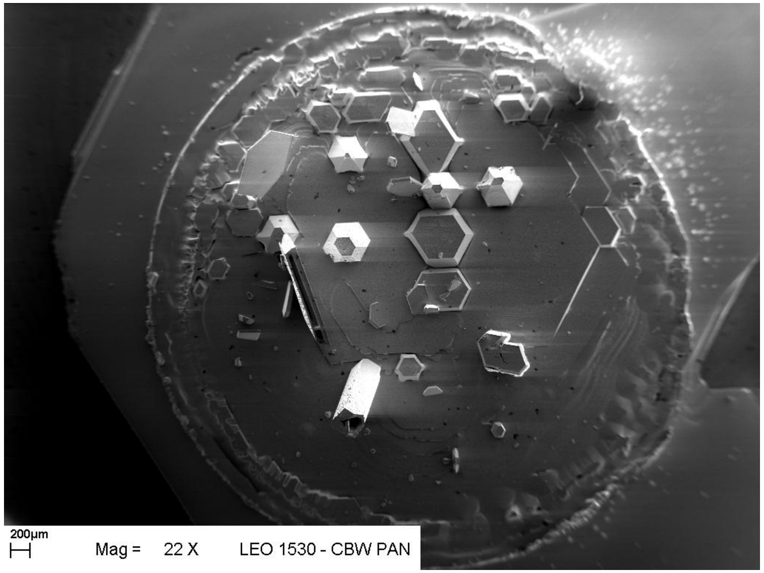
**The polarity of the GaN seed's surface is determined and controlled by the Ga solution and its impurities.**
**The crystallization process is perturbed when the nitrogen polar surface (000-1) of the GaN substrate is exposed to the liquid gallium.**
**The presence of several growth centers is observed. The simultaneous nucleation and growth of randomly oriented crystals is also noticed.**



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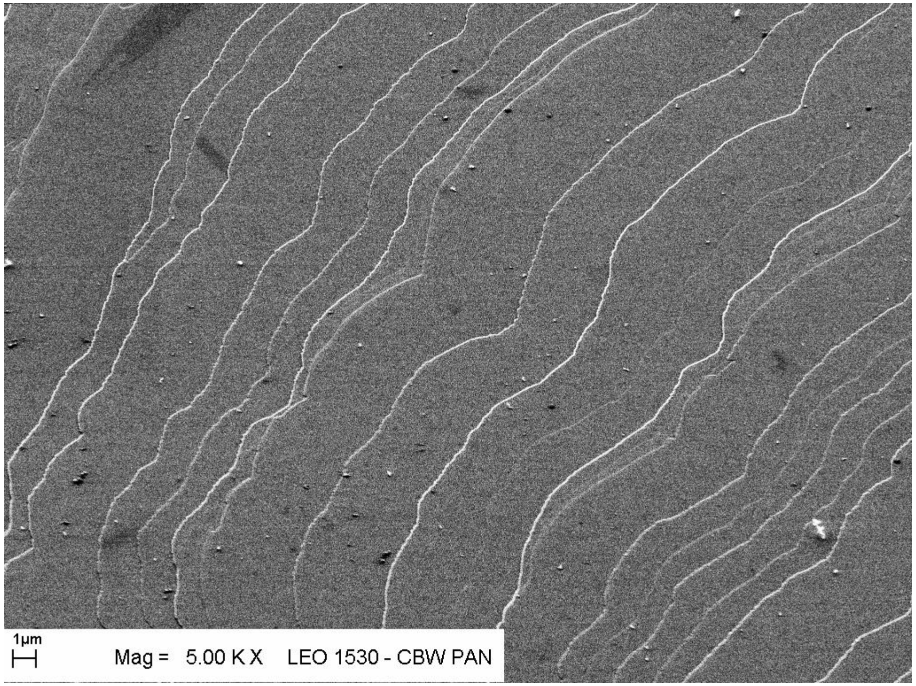
**On the gallium polar surface (0001) the growth mode is macroscopically stable and proceeds by the steps propagation from the center of the sample to its sides.**
**The average growth rate, determined by a comparison of a seed's weight before and after the experiment, is of the order of 1 µm/h.**




**The new deposited material is always n-type with metallic conductivity (~$5 \times 10^{19}$ $cm^{-3}$).**

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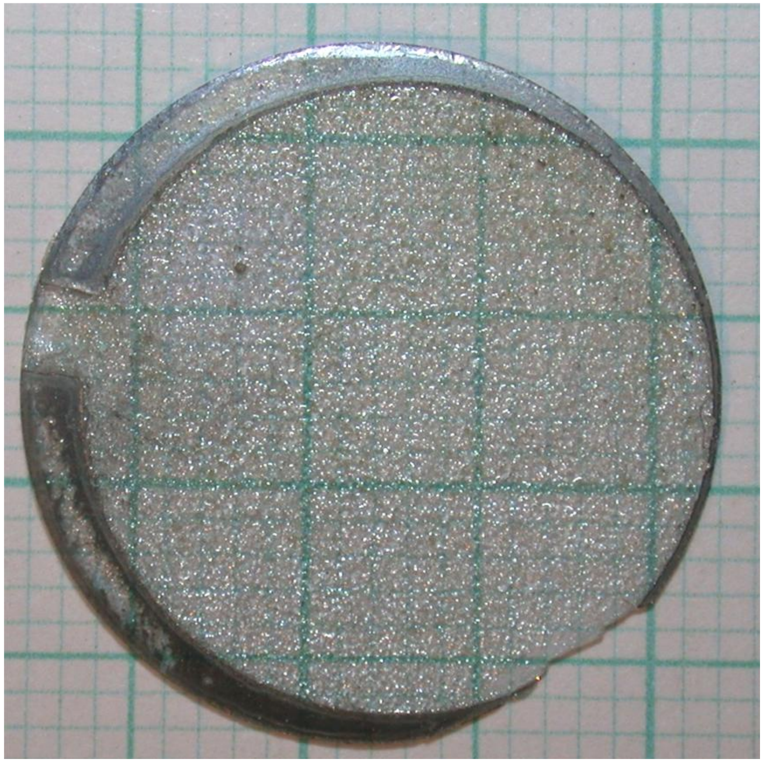
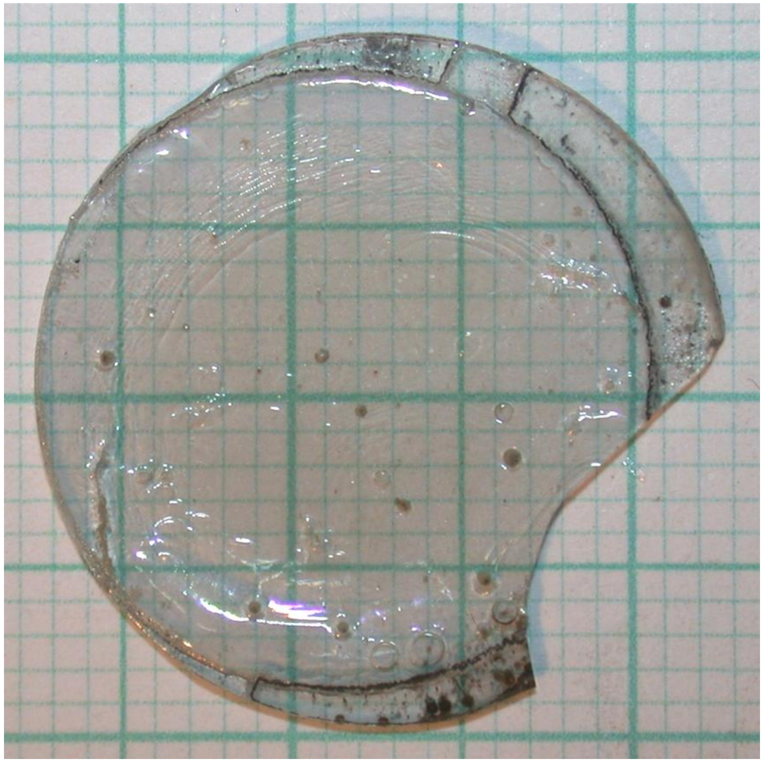
**For crystallization of highly resistive GaN (in the Ga:Mg solution) the new material is grown by stable way on the (000-1) surface of the seed.**





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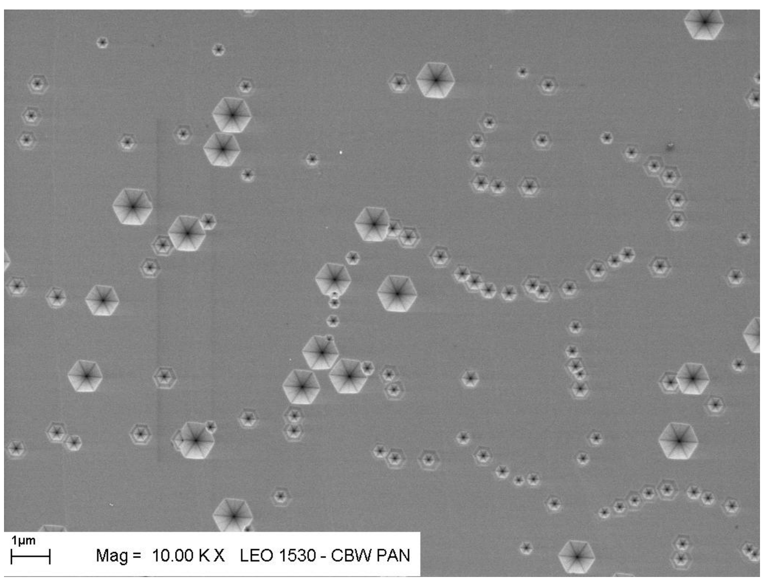
**The average dislocation density in GaN crystallized on the HNPS-GaN is always as low as $10^2$ cm$^{-2}$.**
**The dislocation density in the pressure-grown material on sapphire/GaN templates is of the order of $5 \times 10^7$ cm$^{-2}$.**
**Lower defect density can be obtained when HVPE-GaN is used as a substrate. Then, the dislocation density in the starting material is of the order of $1 \times 10^6$ cm$^{-2}$.**




**on a sapphire/GaN template**


**on free standing HVPE-GaN**

# Seeded Growth
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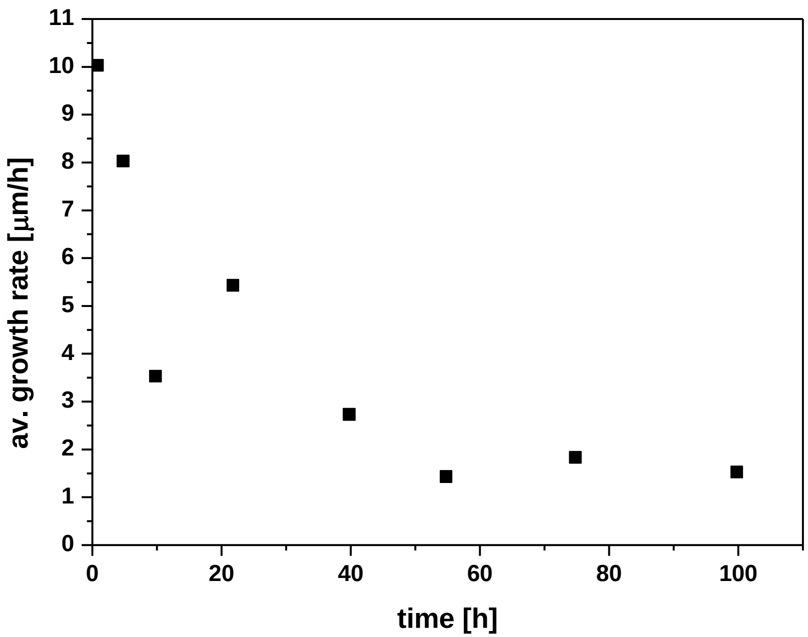
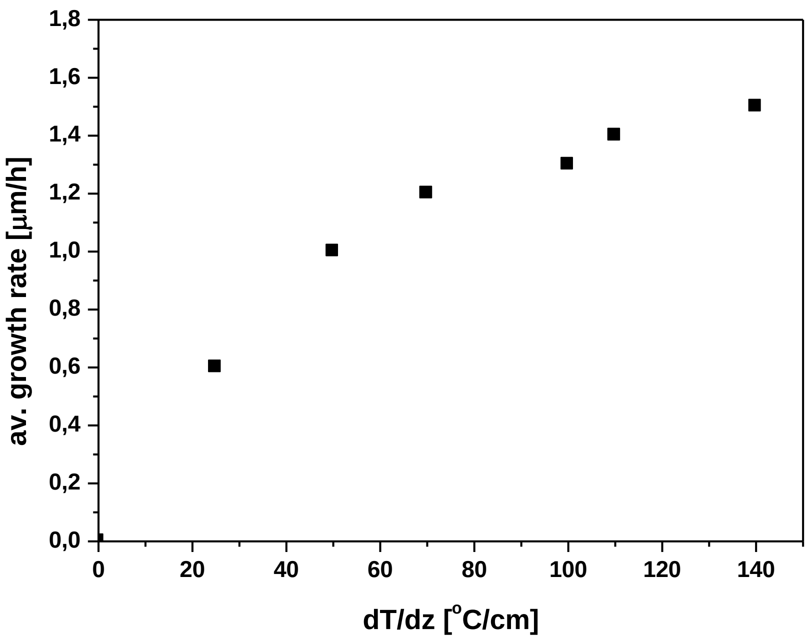
**There are two factors responsible for GaN growth in the c-direction. These factors do not depend on the experimental configurations or the kind of the substrates.**
**For a short time ~30 h. the growth rate is governed mainly by nitrogen transport to the crystallization zone and the observed average growth rate can even attain 10 µm/h. After a longer time ~100 h. the surface kinetic factor becomes more important and the average growth rate decreases to 1 µm/h.**



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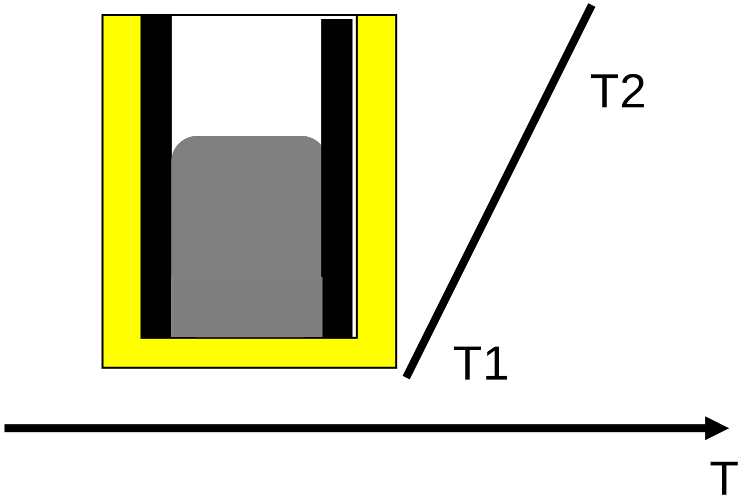
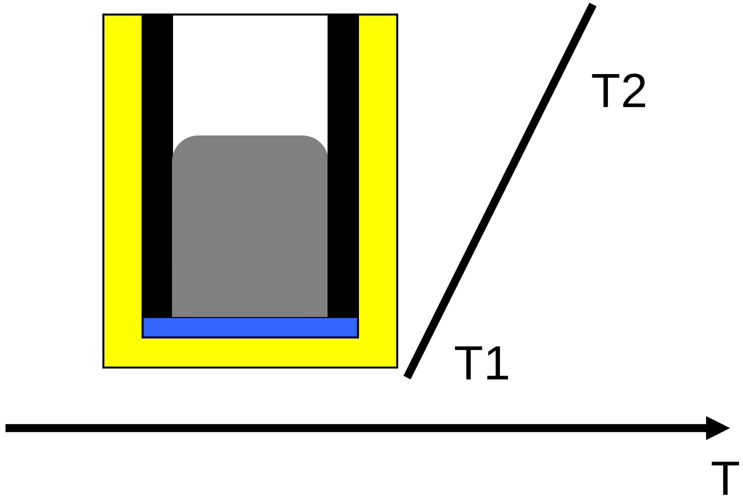
**The analysis of GaN mass, crystallized at configuration with and without seed, confirmed that the growth rate on the seed is governed by surface kinetic.**
**The GaN mass crystallized at the bottom of the crucible without a seed was bigger than the mass crystallized on the seed (with no parasitic growth observed) under the same experimental conditions.**
**Not all the nitrogen atoms from the solution reaching the seed's surface were adsorbed there.**




**total GaN mass = mass at the bottom + mass at the wall**

**200 μm=120 μm+80 μm** **200 μm=80 μm+120 μm**

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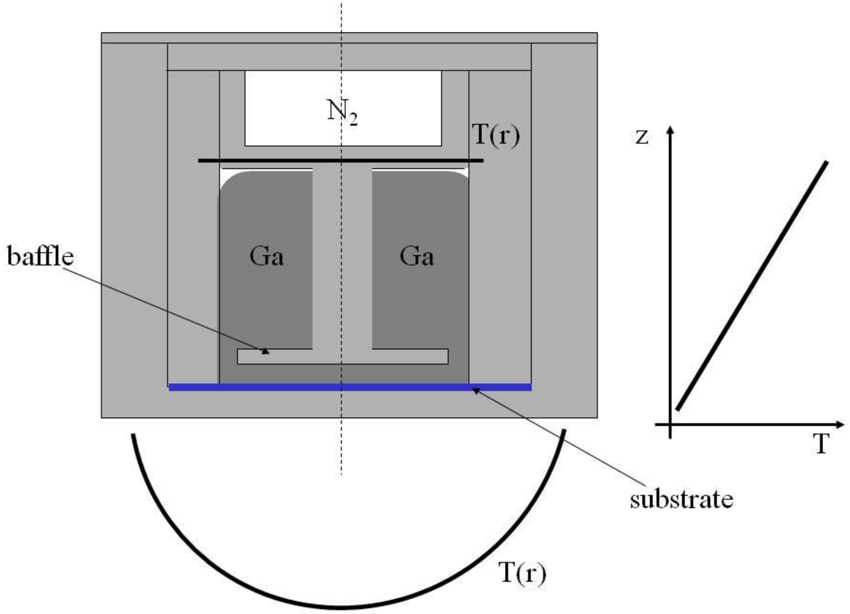
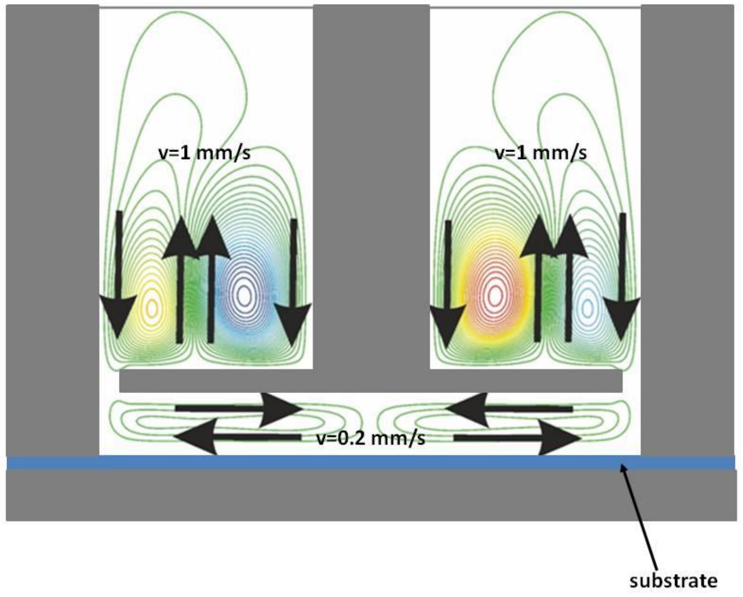
**The finite element calculation is used for modeling the convective transport in the solution.**
**The radial temperature distribution at the bottom of the crucible is approximated as parabolic and the vertical temperature distribution as linear. The radial temperature distribution on the crucible's top is estimated as a constant.**
**Assuming the laminar flow in the gallium the convectional flow velocity in the metal, and the temperature distributions in the liquid, in the seed, and in the crucible wall are determined.**



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**The maximum velocity for the convectional flow above the baffle is of the order of 1mm/s for the used temperature gradients. Under the baffle the convection is very weak. The maximum flow velocities in two rolls reach 0.2 mm/s.**
**Nitrogen is transported to the baffle by a relatively strong convection. The N atoms are dispersed on the baffle and on the sides (opening areas) they are supplied below the baffle to the seed region. Their velocity is low. By very weak convection process the N atoms are transported to the seed.**
**Due to a very low convectional flow velocity the growth can be macroscopically stable. The rate, however, is as slow as 1 μm/h.**