

Cathodoluminescence Microscopy and micro-Raman Spectroscopy of Growth Domains Formed During Epitaxial Lateral Overgrowth of GaN

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The impact of systematically varied growth parameters resulting in differently evolved stages of epitaxial lateral overgrowth GaN (ELOG) structures is comprehensively investigated by spatially and time resolved cathodoluminescence (CL) microscopy and micro-Raman spectroscopy.

Following the deposition of a 2.5 μm MOVPE buffer on (0001) sapphire substrate, a SiO_2 -layer was patterned into a periodic mask of 10 μm wide SiO_2 -stripes along $\langle 1\bar{1}00 \rangle$ separated by 5 μm openings. Subsequently, these identically patterned structures were overgrown by HVPE, systematically varying both growth time and carrier gas composition. In strong dependence on these parameters various stages of lateral overgrowth were achieved. After short growth times selective area growth resulted in the formation of still clearly separated GaN-stripes with triangular cross-section for high hydrogen to nitrogen carrier gas ratio whereas for pure nitrogen carrier gas a trapezoidal cross-section was formed. Gradually increasing the growth time either lead to partly coalesced stripes showing sporadic surface defects or a complete coalescence resulting in an almost flat sample surface, depending on the H_2 to N_2 ratio.

In spite of the distinct differences in the sample topography, striking analogies in the growth characteristics of the HVPE GaN are evidenced by cross-sectional scanning CL microscopy. Similar specific growth domains were found in all samples:

The coherently grown region between the SiO_2 -stripes is characterized by triangular areas emitting weak near bandgap CL centered around 358 nm.

The onset of the lateral overgrowth, i.e. the transition from coherent (0001) growth to facet growth, is always marked by an abrupt increase of luminescence intensity accompanied by the appearance of a broad (e,h)-plasma luminescence band, evidencing high local free carrier concentration. At the very edges of the SiO_2 -stripes the peak maximum of the plasma luminescence is blueshifted as much as 70 meV with respect to (D^0 ,X) in fully relaxed GaN (i.e. 357.2 nm). With advancing lateral overgrowth a redshift of this plasma luminescence is found, visualizing a gradual decrease of the local free carrier concentration. Simultaneously, the (e,h)-plasma becomes less dominant in comparison to the increasing excitonic emission. The (e,h)-plasma emission is clearly restricted to characteristically shaped self-limited growth domains which are confined between the mask edge and the position of first coalescence of the ELO GaN directly above the center of the SiO_2 -stripes.

In the coalescence region itself the (e,h)-plasma band totally vanishes, leading to narrow luminescence lines. While all samples clearly show mask periodic CL features near the interface, almost homogeneous properties are achieved after sufficiently long growth times. At about 15 μm distance from the interface an abrupt transition of both luminescence intensity and lineshape is observed, although absolutely no specific features are visible in corresponding cross-sectional scanning electron microscopy images. Following this transition, up to the surface sharp excitonic luminescence lines (FWHM=5 meV) are dominant both between and on top of the SiO_2 -stripes, proving excellent crystallographic quality.

The relaxation and recombination dynamics inside the different specific growth domains are investigated applying time resolved CL microscopy.

To correlate the optical and structural properties on a microscopic scale the CL results are accomplished by micro-Raman spectroscopy mappings directly visualizing the local strain as well as the free carrier concentration.

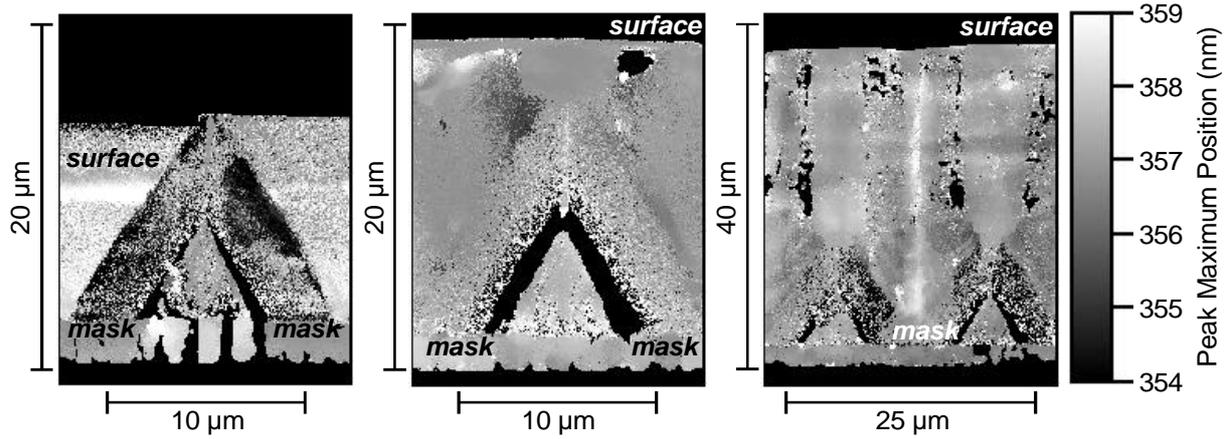


Fig. 1.: Cross-sectional CL wavelength images of ELOG structures exhibiting different stages of lateral overgrowth, taken perpendicular to the SiO₂ mask stripes

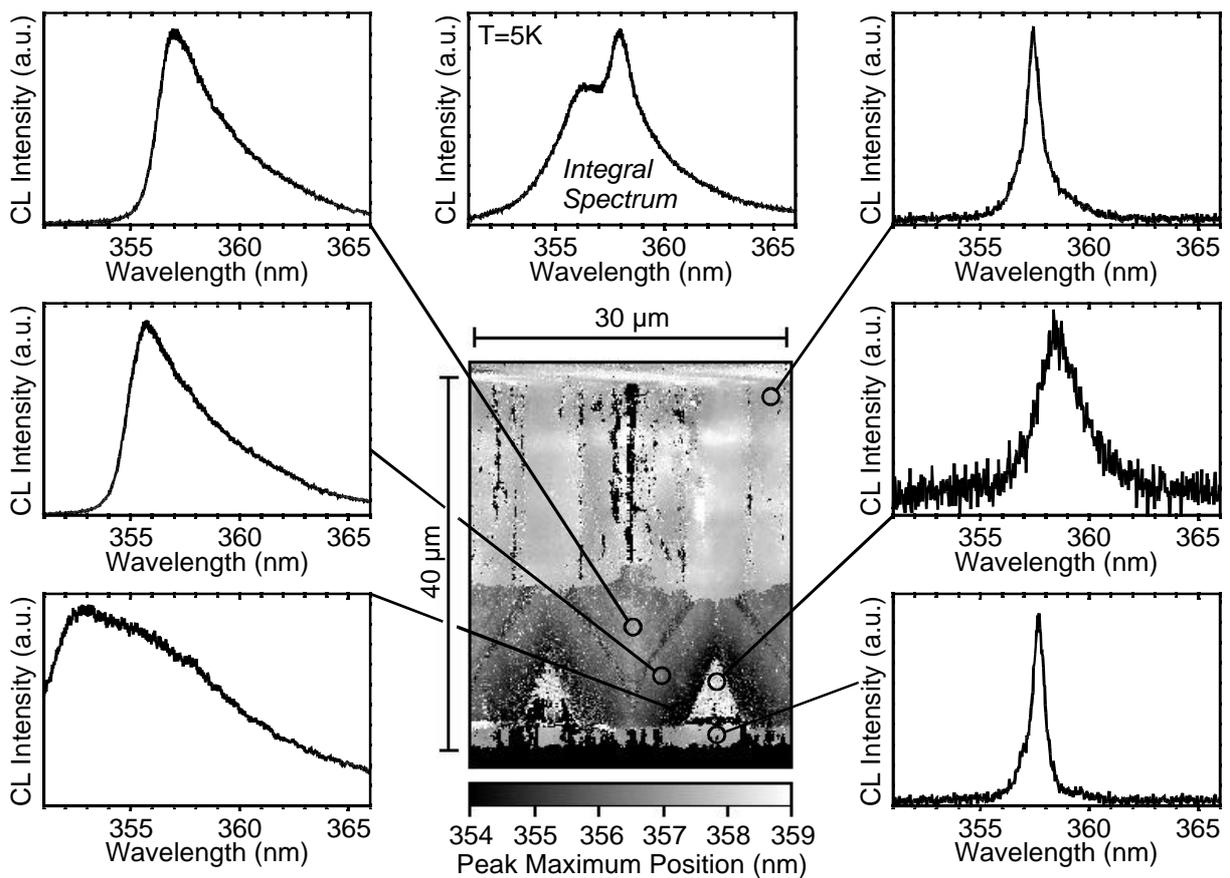


Fig. 2.: Set of local low-temperature CL spectra typical for the different growth domains, taken at the sampling positions indicated in the cross-sectional CL wavelength image