# Time-modulated growth of thick GaN by vapor phase epitaxy: suppression of dislocations

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Homoepitaxy is of importance for GaN for its numerous applications in electronics and optoelectronics. However, it is difficult to get an appropriate epitaxy-ready GaN substrate. One of the key issues is the requirement of low defect density, thick GaN substrate, since the threading dislocations from the substrate extend into the upper layers. Renewed interest in hydride vapor phase epitaxy (HVPE) is therefore motivated since this technique allows to grow thick GaN at high deposition rates. Much effort, i.e., introduction of buffer layers [(1)], pretreatment of substrates [(2)], has made for controlling and minimizing the defect density by optimizing the growth of the thick GaN films.

In this paper time-modulated growth of GaN (TIMG) is introduced as an alternative trial to suppress and minize the defect density. The GaN layers were grown on *c*-$Al_2O_3$ (0001) substrates in a home-built VPE system. The Ga source was GaCl in-situ formed in the upstream of the reactor by reacting HCl gas with liquid gallium at ~ 850 $^{o}$C. Nitrogen was used as a carrier gas. The substrate holder was placed in the down stream region of the reactor, where the GaCl and $NH_3$ mixed at about 1050 $^{o}$C. The flow of HCl was switched on and off in turn for growth or no deposition at growth conditions to realize the time-modulated growth process.

Transmission electron microscopy, X-ray diffraction, and photoluminescence were carried out to study the cross-sectional structure and crystal structure as well as the crystal quality.

We demonstrate that the crystal quality of thick GaN is greatly improved in contrast to that directly deposited on c-$Al_2O_3$ (0001) without modulating the growth process. Transmission electron microscopy observations show that there is an obvious break between the defective initial layer and well-structured subsequent layer due to switching off HCl, i.e., switching off the growth of GaN at growth conditions for a certain time. No similar break was found in subsequent grown layer though there was also a break of the growth. This reveals that separated layers of GaN may be grown in-situ at the same growth condition by TIMG mode. The break of growth may be helpful to the reconstruction of the layer surface as well as the relaxation of strain and stress at surface. TEM picture shows that a great deal of defects have been suppressed within the initial growth layer (~7μm) (see figure 1).

Figure 1 Cross-sectional structure of the initial layer and consequent layer of TIMG growth GaN

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