Epitaxial Lateral Overgrowth and Beyond

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Since there is no GaN bulk single crystal commercially available, the whole technological development of GaN based devices relies on heteroepitaxy. Most of the current device structures are grown on sapphire or 6H-SiC. However, since their lattice parameters and thermal expansion coefficients are not well matched to GaN, the epitaxial growth generates huge densities of defects, with threading dislocations (TDs) being the most prevalent (10^9 to $10^{11}cm^{-2}$). Actually this large density of TD in GaN drastically limits the performances and operating lifetime of nitride based devices. Though laser diodes (LDs) have been demonstrated in the late nineties with such defective layers, the real breakthrough in laser technology has been the dramatic improvement of the laser diode lifetime at the end of 1997, with the lifetime reaching 10000 hours. This has been made possible by the implementation of the Epitaxial Lateral Overgrowth technology (ELO), which significantly reduces the dislocation density to below 10^7cm^{-2}. In the ELO technology, parts of the highly dislocated starting GaN are masked, after which growth is restarted. At the beginning of the second growth step, deposition only occurs within the openings with no deposition observed on the mask. This is referred to as Selective Area Epitaxy (SAE). The TDs are prevented from propagating into the overlayer by the mask, whereas GaN grown above the opening (coherent growth) keeps the same TD density as the template, at least during the early stages of the growth. Currently, two main ELO technologies exist: the simpler one involves a single growth step on the striped openings. In this one-step-ELO (1S-ELO), growth in the opening remains in registry with the GaN template underneath (coherent part), whereas GaN over the mask extends laterally (wings). This leads to two grades, namely highly dislocated GaN above the openings, and low dislocation density GaN above the masks. With this technique, devices have to be fabricated on the wings. Conversely, in the two-step-ELO (2S-ELO) process, the growth conditions of the first step are monitored to obtain triangular stripes. Inside these stripes, the threading dislocations arising from the templates are bent by 90°when they encounter the inclined lateral facet. In the second step, the growth conditions are modified to achieve full coalescence. In this two-step-ELO, only the coalescence boundaries are defective. The ELO technology produces high quality GaN, with TD densities in the mid 10^7cm^{-2}. Numerous modifications of the ELO process have been proposed in order either to avoid technological steps (mask less ELO) or to improve it (pendeo epitaxy). To further reduce the TD density, multiple step ELO or pendeo have also been implemented. However, even ELO quality GaN is not good enough for the next generation of LDs. ELO samples do not yet offer a full surface suitable for laser technology. What is needed for LDs with at least 30 mW output power, is high quality free standing GaN with TDs close to or even below 10^6cm^{-2}. To reach this crystalline perfection, elaborated technologies are currently being implemented. They, at some stage, involve TD reduction mechanisms occurring in the ELO process. Self supported GaN with at least ELO quality at an affordable cost is believed to be the next breakthrough in the GaN technology.