High quality GaN templates by coalescence overgrowth of GaN nanowires by MOCVD

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GaN has recently gained renewed scientific attention as one of the most promising wide-bandgap semiconductor materials for high-frequency power devices [1]. Due to the difficulty to produce GaN crystals from the melt and the high cost of GaN bulk substrates, the heteroepitaxy approach has been widely used for fabrication of GaN-based electronic and optolectronic devices [2, 3]. The crystal quality of heteroepitaxial GaN layers is strongly influenced by the lattice and thermal mismatches with the substrate, resulting in strain and structural defects which limit the device performance. To solve these issues, homoepitaxy seems to be the best approach enabling the reduction of the dislocation density in the GaN layers and providing enough crystalline quality to improve the production of vertical electronic power devices. An alternative to the use of GaN bulk substrates is to obtain high-quality coalescence overgrowth templates from a patterned-grown GaN nanowires (NWs). Previous studies have demonstrated that the quality of the coalesced layer is directly related to the regularity and the quality of the NW array [4].

In this work, we study the dependence of the NW reformation and coalescence experimental growth conditions on the quality and morphology of a subsequent 2-µm thick GaN layer grown by Metal Organic Chemical Deposition (MOCVD). For that, different annealing conditions together with different nucleation temperatures and V/III ratios have been investigated in terms of effects on the properties of the subsequent GaN film. The structural quality of the homoepitaxial GaN films has been evaluated by high-resolution X-ray diffraction, revealing a dislocation density in the order of $2x10^7$ cm^{-2}. Morphological studies performed with Atomic Force Microscopy (AFM) over an area of 10x10 $µm^2$ have shown smooth surfaces with the rms values between 0.12-0.15 nm. Atomically step-liked surface area where no spiral steps have been observed suggests that the growth took place following the step-flow mode. The sample with the smoothest surface had the lowest screw dislocation density, the lowest value of strain along the *c*-axis and the highest transmittance. The thermal conductivity measurements performed by time-domain thermoreflectance (TDTR) revealed that the smoothest sample exhibits an out-of-plane thermal conductivity of k= 206 W/mK, approaching the bulk value. This improvement in the quality of the GaN layers arises from the optimization of the reformation process where different annealing and nucleation conditions have been employed. In that regard, we conclude that annealing at an optimized temperature in presence of ammonia followed by a nucleation under high V/III ratio lead to the best properties among all compared samples.

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