HRTEM and LACBED methods for defects recognition in GaN epilayers

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Structural characterisation of various GaN epilayers has been performed using a JEM 3010 (300 kV) Jeol microscope on cross-sectional and planar view samples.

Epitaxial GaN used in blue-green light emitting diodes and lasers has a high density of structural defects mostly due to a lack of lattice matched substrates. The most commonly used substrates are sapphire, with about 13% lattice mismatch, and SiC, with a mismatch of about 3.5% and with better thermal expansion coefficients compared to GaN. Moreover, the high thermal conductivity and the availability of conducting as well as semi-insulating substrates make SiC attractive for the realization of both transistors and optoelectronic devices. In the case of GaN epitaxy the use of off-oriented instead of exact-oriented SiC substrates resulted in an improved surface smoothness and reduced dislocation density under optimized step flow growth conditions.

Some types of defects are typical for GaN epilayers: stacking faults, threading dislocations, inversion domain boundaries, stacking mismatch boundaries and nanopipes. Furthermore, domains of cubic GaN in the predominantly wurtzite material are often found in epitaxially grown GaN with (111) cubic planes parallel to (0001) hexagonal close packed planes. Polytypism is a disadvantage because it makes the growth of high quality single phase epilayers more difficult. On the other hand, it offers the potential advantage of growing polytype based, lattice matched and coherent structures. There is only a small difference in the band gap of cubic and hexagonal GaN polytypes.

Heteroepitaxial GaN layers grown on sapphire by metal organic vapour phase epitaxy (MOVPE) have been characterised by conventional transmission electron microscopy (TEM) on planar and cross-sectional samples, Large Angle Convergent Beam Electron Diffraction (LACBED) and by high-resolution transmission electron microscopy (HRTEM). Hollow tubes termed nanopipes were resolved on planar view and cross-sections of heteroepitaxial GaN. For advanced studies of the nature of nanopipes the LACBED method was employed. The recognition between perfect structure and screw distortion around nanopipes was performed with high accuracy using Zone Axis LACBED images. This technique is simple and is useful in determining edge and screw type dislocations when the dislocation line is in the foil plane and is perpendicular to the electron beam direction. In this communication a new approach is proposed for the analysis of nanopipes directly on a non-tilted plane-view TEM specimens using ZAP-LACBED. In parallel, the nature and types of nanopipes were evaluated.

In the case of heteroepitaxial GaN layers grown on vicinal SiC substrate cubic GaN inclusions were found as colonies of triangular pyramids inside hexagonal GaN matrix. The size of c-GaN inclusions is in the range 2-16 nm with average lateral diameter near 5 nm. The mechanism of self-assembly formation of pyramidal dots of cubic structure inside hexagonal epilayer is strictly connected with strain induced precipitation and can be interpreted as local stress accommodation. Integrated characterization consisting of conventional TEM, HRTEM and LACBED methods is recommended for complex structure of GaN epilayers.