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主　論　文　の　要　旨

論文題目　**Growth and characterization of nonpolar m-plane GaN on bulk GaN substrates: prospects of high-performance electronic devices**
（m 面バルク GaN 基板上への非極性 GaN の成長とその評価：高性能電子デバイス創成の可能性）

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論　文　内　容　の　要　旨

GaN is an attractive material for optoelectronics and high-power electronics applications, due to its direct wide band gap, high electron mobility, high electron saturation velocity, high stability and conductivity. GaN materials grown in nonpolar orientations (*a*- or *m*-plane) are devoid of spontaneous polarization and piezoelectric fields which can enable high-performance electronic devices due to the suppression of the quantum-confined Stark effect. As a result, extensive and ongoing research efforts have been devoted to the growth and characterization of nonpolar nitrides worldwide in order to better comprehend their material properties and challenges. Moreover, the advent of low defect lattice-matched bulk GaN substrates has provided a significant progress for high-quality GaN crystals, and improved performance of vertical GaN devices. However, the metalorganic vapor phase epitaxy (MOVPE) growth of homoepitaxial *m*-plane GaN produces very rough surface morphologies and induces high unintentional impurity incorporation, which hinders further progress in device performance and reliability. Hence, epitaxial growth engineering is crucial and the most cost-effective measure to achieve optimal material and device properties.

In this thesis, I introduced two growth engineering techniques for achieving high-quality homoepitaxial *m*-plane GaN films. The first approach is to optimize the V/III ratio and the second one is to use nitrogen (N_2) carrier gas instead of conventional hydrogen (H_2) during the MOVPE growth. I successfully demonstrated that by controlling the V/III ratio, the density of surface hillocks can be decreased and the impurity contents can be reduced, ultimately enabling low leakage currents. In addition, by choosing N_2 carrier gas for the homoepitaxy of *m*-plane GaN crystals, I proved that the surface morphology can be significantly improved by suppressing pyramidal hillocks which in turn leads to the reduction of the concentrations of residual oxygen, carbon and silicon impurities. Moreover, N_2 carrier gas promotes higher crystalline quality by mitigating the formation of regrowth related dislocations. Furthermore, I conducted electrical characterizations of *m*-plane GaN based vertical Schottky barrier diodes (SBDs). Very low leakage current densities of the order of 10^{-10} A/cm^2 at -5 V were obtained for vertical SBDs fabricated on *m*-plane GaN samples grown at optimized conditions. Also, the leakage current paths in vertical *m*-plane GaN SBDs were found to be concentrated on the pyramidal hillock facets that are inclined toward [0001] and it is believed that this phenomenon is caused by the higher density of free electrons and the resulting band gap narrowing.

In conclusion, this thesis presents original and very important findings related to the growth optimization and characterization of nonpolar *m*-plane GaN on bulk GaN substrates. These results show good prospects for the development of high-performance electronic devices based on nonpolar GaN materials.