主　論　文　の　要　約

論文題目　**Study on growth of orientation-controlled GaN films on Si(001) for optoelectronic applications**
（オプトエレクトロニクスアプリケーションに向けたSi(001)上GaN配向制御に関する研究）

氏　　名　李　浩準

論　文　内　容　の　要　約

Making a good choice of substrate is essential for the growth of III-nitride compound semiconductor materials such as GaN, whose growth features are strongly dependent on characteristics such as substrate orientation. To synthesize GaN films on a given substrate, it is most important to consider physical properties and parameters such as the crystalline orientation, strain, and stress, which are all significant factors influencing the outcome of the growth process. These parameters are closely related to the lattice constants and structural orientation of the template substrate. Traditionally, direct growth of GaN layers on conventional foreign substrates (sapphire and silicon) produces films with high densities of crystalline defects, such as threading dislocations, and very rough surface morphologies, mainly due to the lattice mismatches between these substrates and the grown materials. Several research groups have attempted to overcome these issues and improve the crystal quality by reducing the lattice mismatch to avoid the generation of dislocations and achieve smooth film surfaces. This study introduces an intriguing and novel approach, involving the use of compliant substrates that can accommodate part of the strain during the growth of strained epitaxial films. In this new technique, an additional thin film of material is incorporated to effectively decrease defects, including the threading and misfit dislocations that were previously considered to be unavoidable effects of lattice mismatch. However, controlling the crystallographic orientation of thin films through epitaxy independently of the crystalline orientation of the substrate appears to be very challenging.

In this thesis, we introduce a technique for controlling the orientation of GaN films grown on Si(001) substrates, which includes implementing a directionally sputtered AlN (DS-AlN) buffer layer. In addition, a new approach to achieving single-crystalline GaN is presented. To synthetize the DS-AlN buffer layer, we use a long-throw sputtering system featuring a long target-to-substrate (T-S) distance of 250 mm, which, unlike its conventional counterpart with a T-S distance of 50–100 mm, enables us to deposit uniform, oriented sputtered films. We experiment with two parameters to control the crystal property (single or polycrystalline) and orientation: (i) the azimuth angle of the substrate, i.e., the loading direction of the Si(001) substrate relative to the Al target along the Si[001] and Si[110] directions without rotation, and (ii) the substrate tilt angle, or sputtering angle, i.e., the angle between the substrate and the stage. We succeed in growing single-crystalline GaN films in semipolar orientations, including the $(10\bar{1}3)$ and $(10\bar{1}5)$ planes, but these samples exhibit rough surface morphologies with uncoalesced areas and relatively high pit densities.

In an attempt to grow fully coalesced films with smooth surfaces, we investigate the effect of V/III ratio on surface morphology. GaN epitaxies on DS-AlN/Si(001) templates are conducted under similar growth conditions for V/III ratios of 220, 45, and 36, with the samples grown at the lowest V/III ratio (36) displaying the best surface morphologies. Mirror-like surfaces are observed for the semipolar $(10\bar{1}3)$ GaN films, but the semipolar $(10\bar{1}5)$ GaN films have slightly rough surfaces. We also find that the grown semipolar GaN samples have high densities of stacking faults, and through a Si substrate removal process, we confirm high densities of inversion domains (IDs) on the N faces of the samples. We succeed in improving the crystalline quality of the semipolar GaN layers by decreasing (i) the SF density through an epitaxial lateral overgrowth process and (ii) the ID density by the insertion of 25 pairs of AlN/GaN superlattice interlayers.