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主　論　文　の　要　旨

論文題目　**Study on position-controlled GaN nanorod arrays and their application to three dimensional light emitting diodes**
(窒化ガリウムナノ構造の選択成長と 3 次元発光ダイオードに関する研究)

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論　文　内　容　の　要　旨

As reported in this thesis, the realization and characterization of artificially position-controlled gallium nitride (GaN) nanorods have been investigated to establish nanostructure arrays for GaN-based core-shell architecture embedded three-dimensional (3D) light-emitting diodes (LEDs). The basic strategies for the selective area growth (SAG) of GaN nanorod arrays are (i) the utilization of catalyst-free metalorganic chemical vapor deposition (MOCVD) for material synthesis, (ii) the deployment of an amorphous growth mask such as SiO_2 or SiN for position-controlled growth, (iii) the use of a *c*-axis-oriented thick GaN underlayer as an epitaxial seed and conducting layer, and (iv) the use of the well-established MOCVD technique for heteroepitaxy and the growth of the LED structure. The systematic position-controlled and selective growth of GaN nanorod arrays was advanced and successfully demonstrated using these strategies. In addition, the formation mechanism, the physical and optical properties of the grown GaN nanorod arrays, and their core-shell architecture were investigated in more detail.

First, pulsed-mode MOCVD growth was carried out to realize the selective growth of GaN nanorod arrays with shape-controlled GaN nanorods. In particular, the effect of the gas injection and interruption timing on pulsed-mode MOCVD growth were investigated. Also, the influence of growth conditions such as the temperature, pressure, patterning, and V/III ratio on SAG GaN nanorod arrays was studied. Additionally, the physical and optical properties of grown GaN nanorod arrays under different synthesis conditions were examined by high-resolution transmission electron microscopy (HR-TEM) and photoluminescence (PL) measurement. Next, highly-ordered, position-controlled GaN nanorod based $In_xGa_{1-x}N$/GaN multiple-quantum-wells (MQWs) core-shell architecture arrays were synthesized by MOCVD. In particular, the possibility of using GaN nanorod arrays as a basal template for the growth of $In_xGa_{1-x}N$/GaN MQWs was investigated. The structural characteristics of $In_xGa_{1-x}N$/GaN core-shell arrays were inspected by cross-sectional HR-TEM. Also, the luminescent characteristics of the MQWs core-shell architecture were determined by PL and cathodoluminescence (CL) measurements. It was found that the light emission intensity shows different behavior depending on the area of the GaN nanorod $\{1\bar{1}00\}$ *m*-plane sidewalls. Finally, the fabrication and characterization of a 3D-LED structure were demonstrated using $In_xGa_{1-x}N$/GaN core-shell arrays with the growth of *p*-GaN. The temperature and excitation power dependences of the PL measurements were carried out to reveal the physical and optical properties of this structure. The realized 3D-LED showed color-changeable luminescence properties from the green to blue region upon adjusting the external applied bias. This phenomenon might be related to features of the MQWs such as the thickness and the dissimilar indium incorporation rates in $In_xGa_{1-x}N$ quantum-wells caused by different crystal facets of GaN nanorods. These results are essential for realizing effective light emission in the longer-wavelength region. The position-controlled 3D structure grown by MOCVD is expected to lead to substantial opportunities for realizing next-generation optoelectronic technologies