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主　論　文　の　要　旨

論文題目　**Growth and characterization of InGaN-based solar cells**

(InGaN 系太陽電池の成長および特性研究)

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論　文　内　容　の　要　旨

In this thesis, the growth and characterization of InGaN-based solar cells were studied to obtain essential information about the development of highly efficient solar cells. First, a simple p-GaN/i-$In_xGa_{1-x}N$/n-GaN solar cell structure was investigated numerically to understand the effect of piezoelectric fields (P_{pz}) on carrier dynamics. A reliable simulation model was obtained by comparing the experimental results with simulated results, and the same p-i-n InGaN structures were again simulated with and without the effect of P_{pz} (in the simulation, spontaneous polarization remained constant). The results for the sample with P_{pz} indicated a higher short current density (J_{sc}), a staircase-like feature in the I-V curve, a higher open circuit voltage (V_{oc}) with a lower fill factor (FF), and a reduced conversion efficiency (CE) compared to that for the sample without P_{pz}. Moreover, as the fraction of In, x, was increased, the V_{oc} value gradually increased, whereas J_{sc} significantly decreased, leading to reductions in the CE and FF values for the structure with P_{pz}. As a method to solve the problem of current loss, various techniques which can eliminate the P_{pz} have also been simulated. Among these techniques, semipolar (11-22) InGaN/GaN MQWs solar cells were experimentally investigated compared to the conventional polar (0001) structure. Due to the P_{pz} characteristics in the semipolar plane, the quantum-confined Stark effect was negligible in the semipolar sample, unlike in the polar sample. Moreover, the semipolar sample

exhibited a rough surface with arrowhead-like features, while the polar sample had a mirror-like surface. The rough surface morphology of the semipolar sample may result in a high J_{sc} due to the low reflectivity. The In-fluctuation effect was observed in both samples, although a higher degree was observed in the polar sample. For this reason, the semipolar sample exhibited enhanced J_{sc} and FF values. However, since the semipolar sample contained a higher defect density than the polar sample, its overall device performances, particularly V_{oc} and CE, were significantly degraded. We applied the dislocation reduction technique by adding a SiN_x insertion layer, resulting in enhanced photovoltaic properties in the resultant p-i-n InGaN/GaN heterojunction solar cell. To understand the relationship between the photovoltaic behaviors and dislocations, we also prepared a sample without the SiN_x insertion layer. Regarding optical properties, the sample with the SiN_x insertion layer exhibited less non-radiative centers and a stronger In-fluctuation effect due to the decrease in dislocation density. However, the quantum-confined Stark effect was almost negligible in both samples. Regarding electrical properties, the sample with the SiN_x insertion layer showed a reduced saturation current and increased shunt resistance due to the reduced dislocation density. The interrelation between the various photovoltaic properties ranging from V_{oc} to FF and dislocation density was further confirmed by comparing the experimental results with the numerical model.