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論　文　内　容　要　旨

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学位論文題目	Study on Normally-off AlGaN/GaN Heterostructure Field-Effect Transistors with P-GaN Cap Layer (P-GaNキャップ層を有するノーマリオフ型AlGaN/GaNヘテロ構造電界効果トランジスタに関する研究)		

内容要旨

With respect to Silicon-based material, GaN has abundant merits for the application of low power consumption due to its 3.4 eV energy bandgap (1.1 eV for Si). Owing to the unique properties of 2DEG in AlGaN/GaN heterosturcture, GaN-based HFETs have become one of the most attractive research region. However, to alleviate the drawback of normally-on operation in conventional AlGaN/GaN HFETs and satisfy safety requirement, the normally-off HFETs is proposed and become the researching intensive point.

P-GaN gate is a promising candidate method to achieve the normally-off operation. However, the Mg^+ out-diffusion would happened in relatively high epitaxy temperature. Then the blocking layer is essential to alleviate the 2DEG degradation from the Mg^+ out-diffusion. According the experiment result, the 20 nm i-GaN layer is the suitable choice, and the 2DEG characteristic is more close to the normally-on HFET with p-GaN cap layer than other thickness. However, the relatively low threshold voltage need to be concerned.

For further increasing the threshold voltage, the normally-off HFETs with insulator gate was fabricated. By inserting a SiN_x (thickness varied from 0 to 30 nm) layer between the p-GaN cap and the gate electrode, the threshold voltage positive shift from 1 to 8 V obviously. Besides, the introduction of SiN_x is also beneficial for suppressing the gate leakage current and improving the maximum gate voltage swing owing to the high breakdown field of approximately 8.3 MV/cm. The output current-voltage characteristics show that the device with thicker SiN_x needs a higher gate voltage to reach the same current density. This can be ascribed to that the applied gate voltage would partly appear across the

SiN_x layer and partly across the semiconductor. The field-effect channel mobility measurement demonstrated that the SiN_x insulator shows no obvious effect on the 2DEG mobility.

For optimizing the normally-off MISHFETs, the normally-off MISFETs with self-aligned-gate (SAG) were adopted. And the SAG and the conventional gate (CG) were fabricated to confirm the feasibility of the SAG gate. The good ohmic contact of 1.45 Ω·mm contact resistance was obtained by the low-temperature ohmic technique. By employing the SiO_2 as the insulator layer, the Vth is close to 2 V in SAG device. Due to the difference of gate structure in SAG and CG device, the high channel resistance owing to the non-applied voltage region of p-GaN in CG device was discussed. It means that the SAG structure is the more advanced to achieve the good performance in normally-off MISFETs with p-GaN cap layer. Further, based on the low temperature ohmic process, a normally-off MISHFETs with SiN_x insulator layer and gate-first process was fabricated. Due to the 50 nm thickness, the gate swing and the output current density are enhanced to 16 V and 47 mA/mm, respectively. And the Good pinch-off characteristics with threshold voltage of 2.0 V and a field-effect mobility of 1500 $cm^2V^{-1}s^{-1}$ were achieved. And the gate leakage current was remarkably suppressed. The low-temperature ohmic process also exhibits a capability of solution to alleviate the gate degradation during the high-temperature annealing in a gate-first process. Final, the interface state is analyzed, it indicates that the MISHFETs structure still has the issues that need to be optimized.