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A Dual Gate AlGaN/GaN HEMT For High Voltage Switching Applications

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1. Introduction

The wide-band gap material, GaN has attracted for the high power and the high temperature applications due to its high breakdown field, high saturation velocity and low intrinsic carrier generation [1]. Various AlGaN/GaN high electron-mobility transistors (HEMTs) for the microwave applications have been reported because of the high sheet carrier density (10^{13} /cm^2) and the high breakdown field (>3 MV/cm) [2]. The high voltage switch device should endure the high breakdown voltage and decrease the leakage current for suppressing power loss. The dual gate AlGaN/GaN HEMT is suitable for the high voltage switching devices due to the high cut-off frequency and the high breakdown voltage [3].

The purpose of our work is to design and to fabricate a new dual gate AlGaN/GaN HEMT, which exhibits the high breakdown voltage and the low leakage current for the high voltage switching applications. We fabricated both the proposed dual gate AlGaN/GaN HEMT and the conventional AlGaN/GaN HEMT with single gate. The proposed dual gate AlGaN/GaN HEMT does not require any additional insulator deposition process of the conventional AlGaN/GaN HEMT employing the field plate [2,4]. Our experimental results show that the breakdown voltage and the leakage current of the proposed dual gate AlGaN/GaN HEMT are 362 V and 75 nA while the conventional AlGaN/GaN HEMT shows 196 V and 428 nA. The effects of the gate bias and the gate-drain space on the electric characteristics are reported.

2. Structure and Fabrication

Fig. 1 shows the cross-sectional view of the proposed dual gate AlGaN/GaN HEMT. The AlGaN/GaN HEMT structure was grown on a C-plane sapphire substrate by MOCVD. The AlGaN/GaN HEMT structure consists of 3 µm thick, undoped GaN buffer layer grown on an AlN nucleation layer. A 330 Å thickness, undoped $Al_{0.3}Ga_{0.7}N$ layer and a 50 Å thickness, doped $Al_{0.3}Ga_{0.7}N$ layer were grown on the GaN buffer layer for the piezoelectric polarization effects. The mesa is formed by ICP etching for the isolation. Source and drain ohmic contacts are formed with Ti/Al/Ni/Au by annealing 850 ºC for 30 s. The Schottky gate was formed with Pt/Mo/Ti/Au by the lift-off process. The measured sheet electron concentration and the electron mobility are 7.82 x 10^{12} /cm^2 and 1530 cm^2/Vs at the room temperature.

The distance between gate1 and source (L_{gs}), the gate1 length (L_{g1}) and the distance between gate1 and drain (L_{sp}+L_{g2}+L_{gd}) of the proposed HEMT are 2 µm, 2 µm and 10 µm, respectively. The distance between gate1 and drain of the proposed HEMT is designed identical the distance between gate and drain of the conventional HEMT. It should be noticed that the gate1 and the gate2 are simultaneously fabricated and the fabrication of the proposed HEMT does not require any additional process.

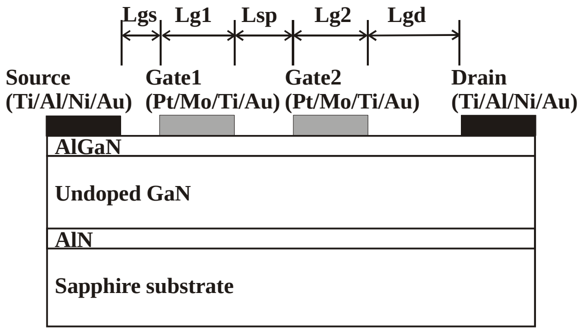

Fig. 1. Cross-sectional view of the proposed dual gate AlGaN/GaN HEMT

3. Experimental Results

The leakage current of the proposed HEMT with various gate2 voltages (V_{G2}) is shown in Fig. 2. The threshold voltages of the proposed HEMT and the conventional HEMT are measured and each other found to be –5.16 V. The leakage is measured under V_{DS} = 5 V and V_{G1} = -6 V. The leakage current of the proposed HEMT decreases as the V_{G2} increases. The leakage currents of proposed HEMT with V_{G2} = 5 V and conventional HEMT are 83 nA and 428 nA. The leakage current of the proposed HEMT decreases compared with that of conventional HEMT because the additional gate (gate2) decreases the electric field concentration at the drain-side-edge of the gate1.

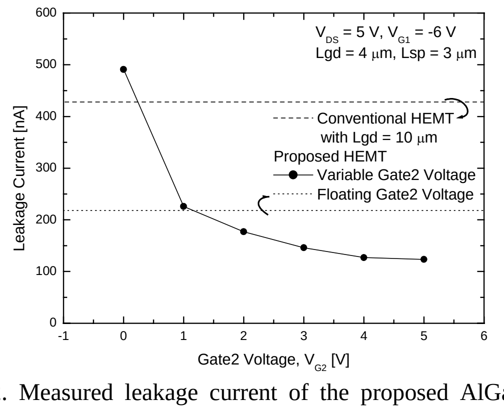

Fig. 2. Measured leakage current of the proposed AlGaN/GaN HEMT with various gate2 voltages

The maximum transconductance, $g_{m.max}$ (at V_{DS} = 5 V) and I_{DS} (at V_{DS} = 5 V and V_{G1} = 0 V) of the proposed HEMT with various gate2 voltages are shown in Fig. 3. The $g_{m.max}$ of the proposed HEMT is not affected by the gate2 voltage and the I_{DS} of proposed HEMT is decreased at the V_{G2} = 5 V. The $g_{m.max}$ of the proposed HEMT does not vary with L_{gd}. The $g_{m.max}$ of the proposed HEMT with the L_{gd} of 5 μm and the L_{gd} of 4 μm are 8.1 mS and 7.7 mS. That of the conventional HEMT is 8.0 mS. The $g_{m.max}$ and I_{DS} of the proposed HEMT are almost identical with those of the conventional HEMT.

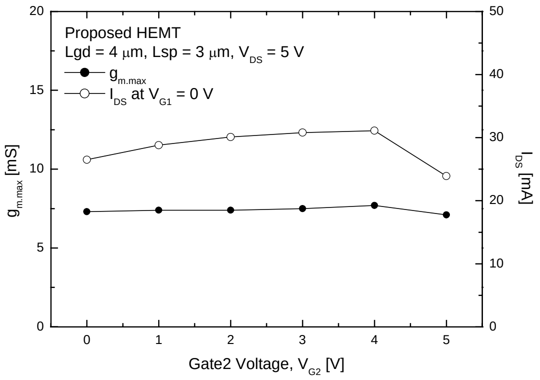

Fig. 3. Measured $g_{m.max}$ and I_{DS} of the proposed AlGaN/GaN HEMT with various gate2 voltages

The leakage current of the proposed HEMT decreases as the L_{gd} increases as shown in Fig. 4. When the gate2 is located away from the drain, the electric field of the gate1 and the leakage current decrease, respectively. The proposed HEMT with floating gate2 and the L_{gd} of 5 μm achieves the lowest leakage current of 75 nA which is less than 20 % of that of conventional HEMT.

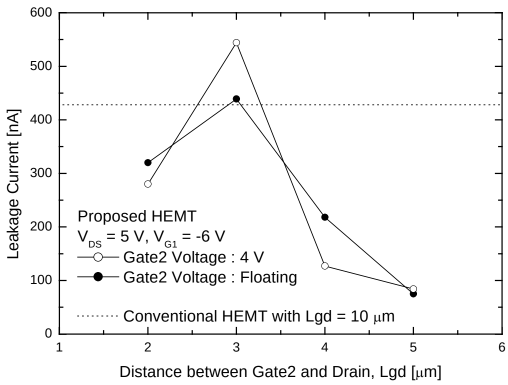

Fig. 4. Measured leakage current of the proposed AlGaN/GaN HEMT with various L_{gd}

The breakdown voltage characteristic of the proposed HEMT with various gate2 voltages is shown in Fig. 5. The breakdown voltage of the proposed HEMT increases compared with that of the conventional HEMT due to its electric field alleviation of the gate1. It may be attributed to the field metal ring effect [5]. The breakdown voltages of the proposed HEMT with V_{G2} = 4 V and V_{G2} = 0 V are 319 V and 295 V, respectively. The proposed HEMT with floating gate2 achieves the highest breakdown voltage of 362 V. The breakdown voltage of the conventional HEMT with single gate is 196 V, which is 54 % of that of the proposed HEMT. Fig. 6 shows the breakdown voltage of the proposed HEMT with various L_{gd}. When the L_{gd} of the proposed HEMT is decreased from 5 μm to 2 μm, the breakdown voltage is degraded from 362 V to 133 V. The distance between gate2 and drain (L_{gd}) of the proposed HEMT determines the electric field concentration of the gate1.

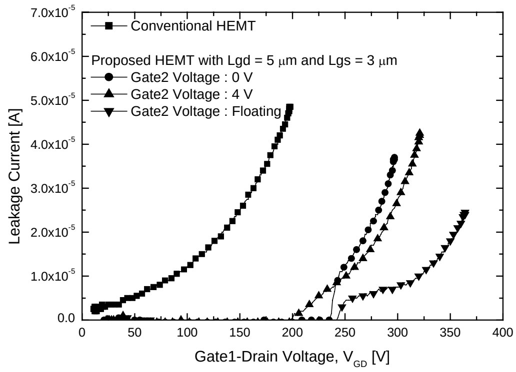

Fig. 5. Measured breakdown voltage characteristics of the proposed AlGaN/GaN HEMT with various gate2 voltages

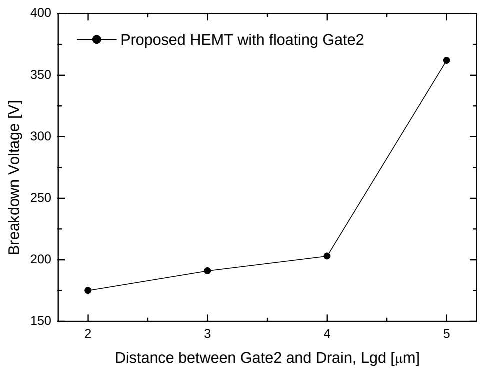

Fig. 6. Measured breakdown voltage of the proposed AlGaN/GaN HEMT with various L_{gd}

4. Conclusions

The dual gate AlGaN/GaN HEMT with high breakdown voltage and low leakage current is proposed and fabricated. The leakage current of the proposed HEMT decreases because the additional gate, gate2 decreases the electric field concentration of the gate1. Our experimental results show that the leakage current of the proposed HEMT is 75 nA, which is less than 20 % of that of the conventional HEMT. The additional gate of the proposed HEMT alleviates the electric field concentration of the gate1 as the field metal ring. The proposed HEMT achieves the breakdown voltage of 362 V while the conventional HEMT shows the breakdown voltage of 196 V. The other electric characteristics of the proposed HEMT are not degraded compared with those of the conventional HEMT.

References

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