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A New Field Plate Structure for Suppression of Leakage Current of AlGaN/GaN HEMTs

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1. Introduction

AlGaN/GaN HEMT is a promising device for high voltage applications due to high critical electric field, high two-dimensional electron gas concentration, high saturation velocity and low intrinsic carrier density [1].

A large leakage current is a critical problem of GaN devices. The Schottky gate contact on AlGaN/GaN heterostructure, considerable amount of dislocations due to the lattice mismatch are located, has been reported as a dominant leakage source [2]. The electric field crowding at the gate edge also results the increase of leakage current [3, 6]. Various edge terminations for GaN devices in order to suppress leakage current such as the floating gate [3], field-modulating plate [4], overlapping gate structure [5], source extended field plate [6], multiple field plates [7] have been reported. The field plate (FP) structures have been widely used to reduce the electric field at the gate edge [4-7].

The purpose of our work is to report and fabricate the AlGaN/GaN HEMTs employing a new field plate structure which suppresses the leakage current. The new field plate structure consists of the gate field plate and an additional field plate. It should be noted that any additional process for the additional field plate structure is not required without sacrifice of electrical on-characteristics. We have fabricated the proposed AlGaN/GaN HEMTs and the leakage current of proposed device is decreased about 42 % compared with that of conventional one.

2. Device Structure and Fabrication

The cross-sectional view of proposed AlGaN/GaN HEMT is shown in Fig. 1. The AlGaN/GaN heterostructure was grown on C-plane sapphire substrate by metal organic chemical vapor deposition (MOCVD). The mesa process is performed for the device isolation by an inductively coupled plasma (ICP) etcher. The source and drain, Ti/Al/Ni/Au (20 nm/80 nm/20 nm/100 nm) were formed by using an e-gun evaporator and annealed at 870 ^{o}C for 30 s under N_2 ambient. The Schottky gate was formed with Pt/Mo/Ti/Au (10 nm/20 nm/20 nm/310 nm) and defined by a lift-off technique. The 400 nm-thick SiO_2 layer for passivation was deposited by ICP-CVD using nitrous oxide, silane and helium at 300 ^{o}C and 35 mTorr. The proposed field plate (FP) structure was formed by evaporating Ni/Au (50 nm/320 nm) on the passivation layer. The proposed FP structure is composed of the gate FP and the additional FP which is located between the gate FP and the drain as shown in Fig. 1.

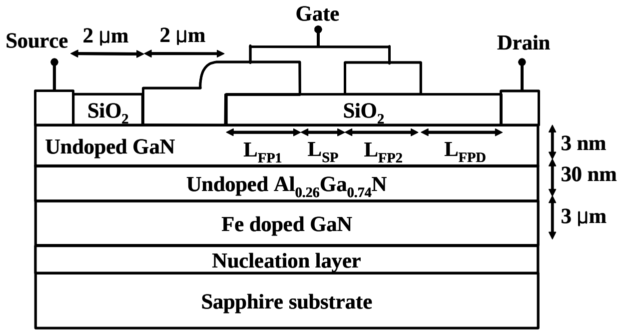

Fig. 1. Cross-sectional view of proposed AlGaN/GaN HEMT

The depletion region of conventional device with a single FP structure is expanded to the drain direction. The electric field concentration is reduced because the single FP reduces the electric field concentration at the gate edge. The number of electric field peaks is two; one is located at the gate edge and the other is located at the single FP edge [3]. The leakage current is significantly influenced by electric field, so that the leakage current of a single FP device is decreased.

The depletion region of proposed device is expanded further than that of single FP device due to the additional FP structure. The proposed device has four electric field peaks due to the additional FP structure while a single FP device has two electric field peaks. The proposed structure reduces the electric field concentration at the gate edge and suppresses leakage current.

3. Experimental Result

The experimental results show that DC on-characteristics of proposed device are identical to those of conventional device. The measured threshold voltage, transconductance and drain current at V_{GS} = 0 V of proposed device are -4.8 V, 105.2 mS/mm and 383.6 mA/mm, respectively. Those of conventional one are -4.7 V, 100.1 mS/mm and 367.4 mA/mm. Both devices sustain a pinch-off characteristic up to V_{DS} = 20 V. The saturation current of proposed device is almost identical to that of conventional one.

Fig. 2 shows the leakage current of proposed device, single FP one and conventional one. The leakage current at V_{GD} = -100 V of proposed device, single FP one and conventional one are 287.9 μA/mm, 438.8 μA/mm and

492.0 μA/mm, respectively. The leakage current of proposed device is 42 % less than that of conventional one. The leakage current of single FP device is 11 % less than that of conventional one. These results demonstrate that the additional FP structure effectively reduces the electric field and expands the depletion layer of proposed device compared with a single FP device.

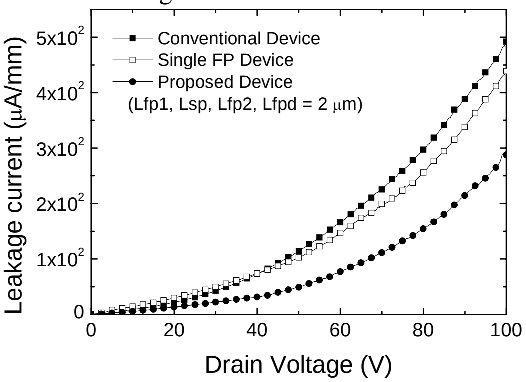

Fig. 2. Leakage current of AlGaN/GaN HEMTs with a proposed FP, a single FP and no FP

The leakage current measurements of proposed devices with various design parameters were performed. Spacing between two field plates (L_{SP}) has a significant effect on the leakage current of proposed device because the electric field distribution between two FPs of proposed device is influenced by L_{SP}. Fig. 3 shows the leakage current of proposed device with various L_{FP1}. When L_{SP} is 2 μm, the proposed device achieves the lowest leakage current of 246.3 μA/mm. L_{SP} of 2 μm is the optimized design parameter for the leakage current suppression of proposed device.

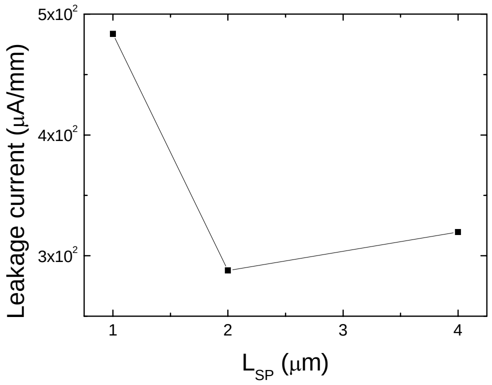

Fig. 3. Leakage current of proposed device with various spacings between two field plates (L_{SP})

Fig. 4 shows the leakage current of proposed device with various the length of gate FP (L_{FP1}). The L_{FP1} determines the electric field at the gate edge. When L_{FP1} is increased, the leakage current is decreased due to the reduction of electric field at the gate edge.

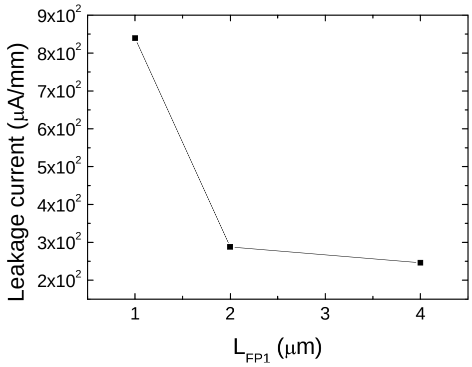

Fig. 4. Measured leakage current of proposed device with various lengths of gate FP (L_{FP1})

The distance between the additional FP and the drain (L_{FPD}) affects the electric field of additional field plate edge. When L_{FPD} is increased, the leakage current of proposed device is decreased due to the decrease of electric field of additional field plate as shown in Fig. 5.

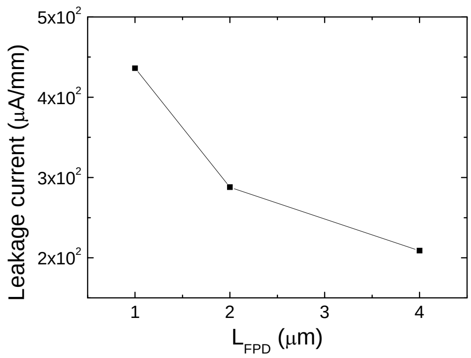

Fig. 5. Measured leakage current of proposed device with various distances between the additional FP and the drain (L_{FPD})

4. Conclusion

We have successfully fabricated the AlGaN/GaN HEMTs employing the new field plate structure to suppress the leakage current without any additional process for the additional field plate structure. The leakage current of proposed device is decreased due to the gate field plate and the additional field plate which expand the depletion layer and reduce the electric field crowding at the gate edge. The leakage current of proposed device is 287.9 μA/mm while that of single FP device and conventional one are 438.8 μA/mm and 492.0 μA/mm.

References

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