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Novel Overlaid Field-Plate for Improvement of Drain *I-V* Characteristics of AlGaN/GaN HEMTs

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Abstract

We propose a novel structure of an AlGaN/GaN HEMT with an overlaid field plate (OLFP) which can be applied bias independently. The OLFP-HEMT demonstrated increase of a drain current associated with reduction of an on-resistance under positive OLFP biasing conditions. This indicates that the OLFP enables intentional increase of carrier density in both a source-to-gate and a gate-to-drain region, resulting in improvement of drain *I-V* characteristics.

1. Introduction

A Field Plate (FP) structure is widely used for reduction of current collapse which is a critical problem of AlGaN/GaN HEMTs [1, 2]. Generally, the FP is on an insulator between a gate and a drain electrode. Thus the FP reduces drain resistance (R_D) increase which is caused by a trapping effect. Recently, effects of the FP have been deeply investigated by controlling an FP bias independently to other electrodes [3]. However, the bias-controllable FP has been only on a gate-to-drain region.

In this paper, we propose a novel overlaid filed plate (OLFP) structure in which the bias-controllable FP is located over whole a source-to-drain region. Not only reduction of the R_{ON} but also increase of the I_{DMAX} has been obtained by reducing both the R_D and the source-resistance (R_S)

2. Concept of OLFP and device structures

The OLFP, which is isolated from any other electrodes electrically and structurally, is located over a whole source-to-drain region on an insulator film (Fig. 1(a)). Therefore, an intentional modulation of two-dimensional electron gas concentration between a source-to-gate and a gate-to-drain region is enabled by independently bias-applying to the OLFP. For example, when a FP voltage (V_{FP}) is more than a threshold voltage of a MIS structure, more electrons can be accumulated at the hetero-interface, so that both a source and a drain resistance can be reduced.

In a fabricated structure, a 150-nm-thick SiO_2 film is used for the insulator. A source-to-gate, a gate, and a gate-to-drain length are 2, 3, and 20 μm respectively (See Fig. 1(a)). For a reference, HEMTs with an independent FP (IFP) only on the gate-to-drain region with several FP lengths (Fig.1 (b)) ware also fabricated. As same as the OLFP, the IFP can be independently biased.

3. Results and Discussion

The OLFP-HEMT demonstrated a maximum drain current (I_{DMAX}) of 184 mA/mm at V_G = +1 V and V_D = +10 V, an R_{ON} of 25 Ω·mm, and a threshold voltage (V_{TH}) of −1.18 V with the OLFP floating (Fig. 2).

The R_{ON} and the I_{DMAX} of the OLFP-HEMT ware compared with IFP-HEMTs with several FP lengths (L_{FP}) at a constant V_{FP} of +10 V (Figs. 3(a) and 3(b)). Here, the device with an L_{FP} of 25 μm is the OLFP-HEMT structure and those with an L_{FP} from 1.5 to 16 μm are IFP-HEMTs ones.

The R_{ON} decreases with increase of the L_{FP} (Fig. 3(a)). On the other hand, the I_{DMAX} for the IFP-HEMT is

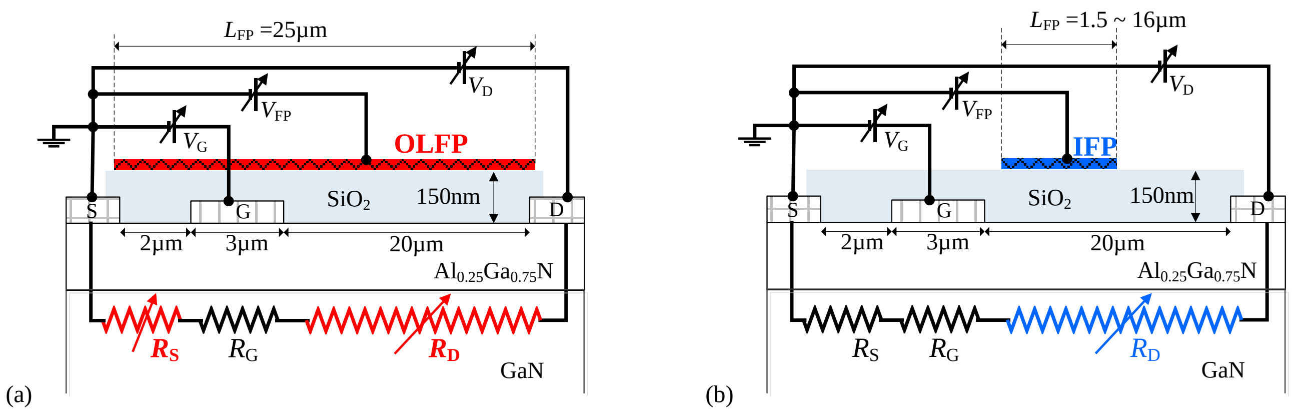

Fig. 1 Schematic cross sections of AlGaN/GaN HEMTs (a) with a novel overlaid FP (OLFP) and (b) with an independent FP (IFP).

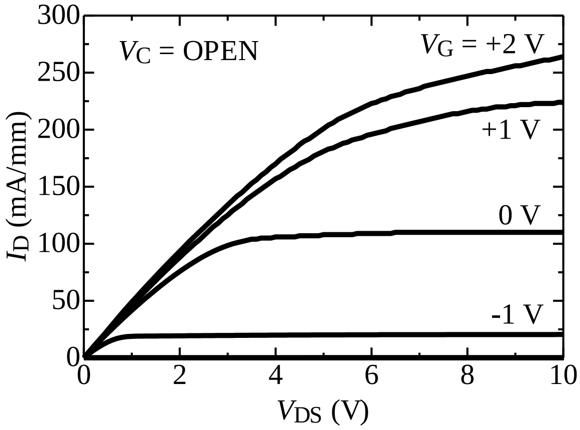

Fig. 2 Drain *I-V* characteristics of the OLFP-HEMT measured under an open V_{FP} condition

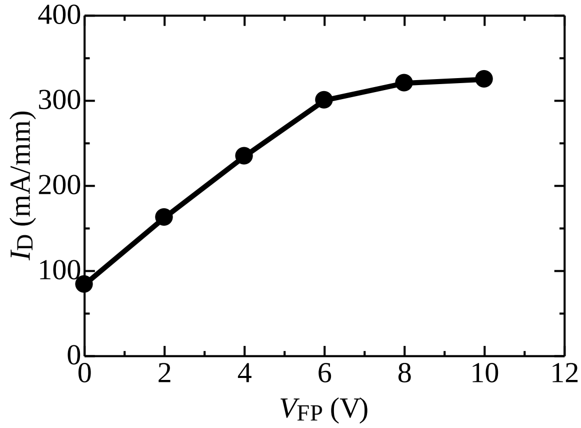

Fig. 4 V_{FP} dependence of I_D at V_G = +2 V, V_D = +10 V (saturation region).

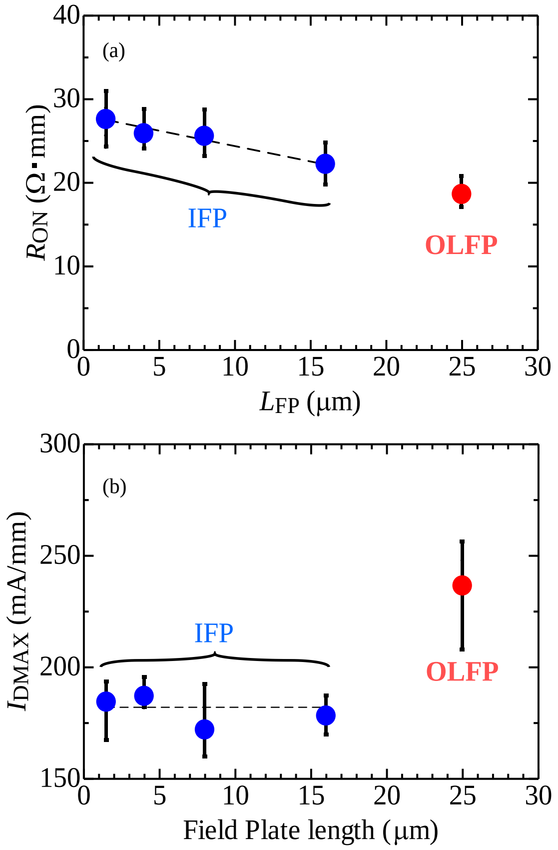

Fig. 3 L_{FP} dependence of (a) R_{ON} and (b) I_{DMAX} at V_G = 1 V and V_D = 5 V (L_{FP} from 1.5 to 16 μm: IFP and L_{FP} = 25 μm: OLFP)

constant independently of the L_{FP}, and the I_{DMAX} of the OLFP-HEMT was 20% more than that of the IFP-FET (Fig. 3(b)). This difference of dependences between the R_{ON} and the I_{DMAX} is reasonable to postulate as follows. In the case of the OLFP-HEMT, decrease of the R_S as well as the R_D results in increase of the I_{DMAX}, and reduction of the R_{ON}. However, in the case of IFP, only the R_D decreases with increase of the L_{FP}, so that the I_{DMAX} is constant.

To investigate how much the drain current (I_D) possibly increases at the maximum using the OLFP, we evaluated V_{FP} dependence on the I_D (Fig. 4). In measurements, the I_D was measured under V_D = 10 V and V_G = 2 V while the V_{FP} was from 0 to 10 V. The I_D increases with increase of the V_{FP} from 0 to 6 V, and then is almost saturated at the V_{FP} more than 6 V. It is noted that the I_D at the V_{FP} of 10 V is three times more than the I_D at a V_{FP} of 0 V. In addition, saturation of the I_D may indicate the R_S could not be reduced any more since a two-dimensional electron gas concentration at the source-to-gate region reached the maximum determined by the AlGaN/GaN heterostructure.

4. Conclusion

R_{ON} reduction and I_D increase of the AlGaN/GaN HEMT have been experimentally realized with a novel overlaid field plate (OLFP), which are owing to the reduction of the R_S as well as the R_D by applying higher positive voltage to the OLFP than a threshold voltage of a MIS structure at the OLFP. Although we applied the OLFP structure to a normally-on HEMT in this paper, it can be applicable even to a normally-off HEMT.

References

[1]Jungwoo Joh, et al. IEEE Electron Device Lett. **29** (2008) 665-667

[2]Huolin Huang, et al. 2014 IEEE transactions on power electronics, **29** (2014) 2164-2173

[3]Guohao Yu, et al., 2013 IEEE Electron Device Lett. **34**, 2013 217-219