A New Dual Field-Plates GaN HEMTs Structure With Improved Break Down and Noise Performance

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Introduction

We have systematically studied the noise, breakdown, and self-heating effect of dual field-plate (DFP) AlGaN/GaN HEMT in which the dual field-plate is connected to the source terminal (DFP-S) and the gate terminal (DFP-G). Although longer FP length promises high power density for high voltage operation, it has a disadvantage of large parasitic capacitance. By adopting DFP metal in HEMT, both DFP-S and DFP-G devices achieved higher gate bias voltage than FP device.

These experimental results indicated that the DFP-G architecture is suitable for low noise applications.

Device structures and fabrication

The HEMT structure consists of 47nm AlGaN/3μm GaN/sapphire substrate. The Al concentration in AlGaN layer is 17%. Mesa isolation was achieved by high density inductively coupled plasma etching. Front-side ohmic contacts of Ti/Al/Ni/Au were formed by lift-off and subsequent annealing 850°C for 30 s under nitrogen ambient. Then 200nm SiO2 was deposited for passivation followed by 1μm long Ni/Au-gates and field-plate were deposited.

There are illustrated in Fig.1. The gate width of HEMTs is 200μm. Structure (a) is the conventional. Structure (b) has longer drain to Source distance (Lds=11μm) which was compared to DFP device. Structure (c) has FP. Structure (d) has the 2nd-FP. Figure 2 show the SEM section of 1μm gate length HEMT with 2nd-FPs, they are connected to source and gate terminal.

Device Characterization

The DC performance of various 1×200 μm²-gate devices were characterized using HP4142 semiconductor parameters analyzer. Figure 3 shows the typical DC current- voltage I_d-V_d characteristic of the DFP GaN HEMT. The DFP-G device has great improvement in the gate leakage characteristics by employing the dual field-plate structure. The gate breakdown voltage of HEMT without FP, HEMT with FP, DFP-S, and DFP-G are 170V, 216V, 237V, and 255V, respectively. The DFP-S and DFP-G are much higher than that of the FP HEMT, which indicates the advantage of the DFP device applications.

Using a pulse system to measure the DC characteristic without thermal effect of a device that suffers from self-heating (Fig.4). We observed self-heating effect with bias conditions V_d=10V and I_d=20mA/mm. The DFP device has more current increase than conventional HEMT and FP device when rid of thermal. It is explained that DFP device has great DC and RF performance if we improved the severe self-heating effect.

To further investigate the surface traps for four device, the low-frequency noise was measured, following a method that is sensitive to the semiconductor surface. Figure 5 demonstrates that the field-plate device exhibit a lower 1/f spectra noise compared to standard device at a I_d=10mA conditions. This is due to the carriers under the drain electrode were suppressed to flow into a deeper channel, avoiding the carriers trapped by surface states near interface, especially DFP-G.

Conclusions

In this study, low frequency noise and breakdown characterization have been done on 1μm dual-field plate GaN HEMTs to investigate the different 2nd field-plate connection. For DFP device, its lower $R_g$, lower 1/f noise higher breakdown voltage is suitable for low noise amplifier and voltage control oscillator applications. It has great potential for DFP device if it was improved self-heating effect.

References


Fig.1 Four gate structure to characterize the FP operation. (a) conventional HEMT, (b) long channel device ( compared with field-plate device ), (c) field-plate HEMT, and (d) dual field-plate HEMT.

Fig.2 SEM cross-section of dual field-plate

Fig.3 The measured results of normalized Id-Vd characteristics for standard and DFP GaN HEMTs.

Table.1 The gate breakdown voltage.

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<th>Breakdown Voltage</th>
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<td>Conventional</td>
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<td>153 V</td>
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Fig.4 Compared the same order current of pulse measurement.

Fig.5 The low-frequency noise spectra for four device.