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Multi channel AlGaN/GaN HEMTs for high breakdown voltage and low leakage current

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1. Introduction

AlGaN/GaN high electron mobility transistors (HEMTs) have attracted a considerable attention for high power, high temperature and high frequency applications due to its wide band-gap properties [1]. Most of GaN devices have been focused on microwave frequency applications.

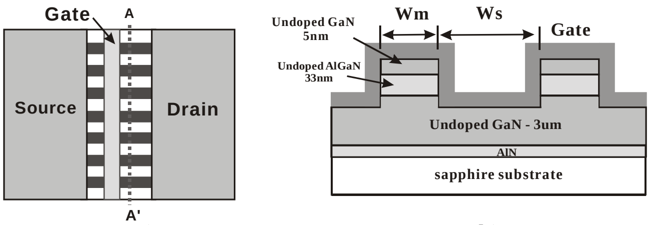
Recently, AlGaN/GaN HEMTs have also been considered for a high voltage power switch and a considerable amount of investigations have been reported good characteristics [2]. In a high power switch, it is well known that a high breakdown voltage with a low on-resistance is necessary. A high breakdown voltage can be obtained due to its high breakdown field strength (>3MV/cm) of GaN. The on-resistance (R_{on}) of AlGaN/GaN HEMTs is also much low due to the high density of a sheet charge and high electron velocities in GaN.

In order to reduce power dissipation, suppression of Schottky gate leakage is very important issues in addition to high breakdown voltage in GaN power switches. In order to increase breakdown voltage and reduce leakage current, several device structures have been employed such as field plate and dual gate [2-3].

The purpose of this work is to report a new multi channel HEMT which increase breakdown voltage and reduce leakage current effectively. Proposed device does not require any additional process because multi channel can be defined by change of mesa design. Our experimental results show that the leakage current is reduced successfully lower than half of conventional device and breakdown voltage is increased considerably.

2. Experiments

We have used AlGaN/GaN epi wafer which was grown on sapphire substrates by MOCVD method as shown in Fig. 1-b. Sheet charge concentration of 7.82×10^{12} /cm^2 and electron mobility of 1530 cm^2/Vs are measured from hall measurement, respectively. Mesa was defined by inductively coupled plasma (ICP) etching for isolation with photo resist mask. Ohmic contact metals (Ti/Al/Ni/Au=20nm/80nm/20nm/100nm) were deposited in a sequence by e-gun evaporator and annealed in 850^{o}C by using RTA for 30s. Schottky contact metals (Pt/Mo/Ti/Au=5nm/20nm/20nm/270nm) were deposited. Top view and cross sectional view of fabricated HEMT are shown in Fig. 1.



a) b)

Fig. 1. a) Top view b) A-A' cross-sectional view of multi channel AlGaN/GaN HEMT (gate length=3μm, total gate width=100μm)

The fabricated multi channel devices have 10 channel of 10μm and 2 channel of 50μm so that total channel width of proposed device is 100μm. It may be noted that the channel width of conventional device is also 100μm.

3. Results and Discussions

Fig. 1 shows variations of breakdown voltage and gate-drain leakage current as a function of Wm. Gate-drain leakage current was measured when the bias voltage between drain and gate are 5V and 40V, respectively.

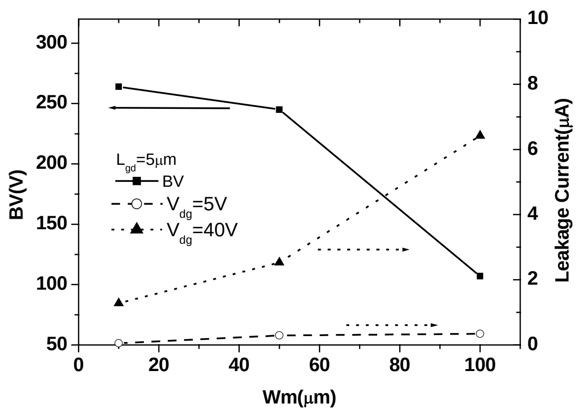


Fig. 2. Breakdown voltage and gate-drain leakage current as a function of Wm

It is well known that the plasma damage on GaN causes a degradation of Schottky characteristics, such as forward and breakdown voltage [4]. Plasma etch damage on sidewall of mesa during mesa etch can also cause increase of the gate-drain leakage current in AlGaN/GaN HEMT device. However, experimental results show that leakage current is rather decreased when the multi channel is employed although the multi channel structures have been suffered from sidewall damaged due to the plasma than that of conventional device. These results indicate that leakage current due to the damage on sidewall of mesa is not significant. Multi channel device exhibits low gate-drain leakage current both in high (V_{dg}=40V) and low (V_{dg}=5V) gate-drain bias. Breakdown voltage is also increased when the multi channel structure is employed. Multi channels with narrow width contain small origin of gate leakage current and premature breakdown, such as dislocation, void and traps on the surface of epi-layer. Therefore, multi channel device shows low leakage current and higher breakdown characteristics compared with conventional device.

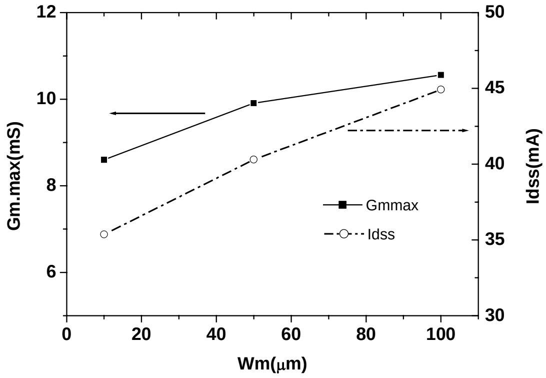


Fig. 3. Gmmax and saturation current (V_g=0, V_d=5V) as a function of Wm

Gmmax and saturation current (Idss) is decreased when the multi channel is employed as shown in Fig. 3. And variation of threshold voltage is negligible.

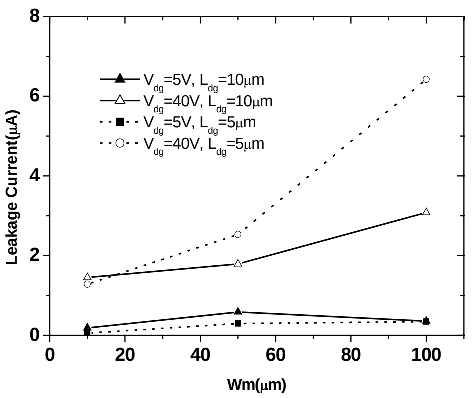


Fig. 4. Leakage currents as a function of various V_{gd} , L_{gd} and Wm

We compared the gate-drain leakage current and the breakdown voltage as a function of the length between gate and drain. Fig. 4 shows gate-drain leakage current of devices of which L_{gd} is 5μm and 10μm when drain-gate bias is 5V and 40V. When drain-gate bias of 5V is applied, variations of drain-gate leakage current are small regardless of the L_{gd} and Wm. When drain-gate bias is 40V in the conventional device, the leakage current of the device of which L_{gd} is 5μm was larger than that of the device of which L_{gd} is 10μm due to the higher electric field in narrow space between the gate and the drain. However, the variation of leakage current by L_{gd} in multi channel device is decreased as the number of channel is increased due to the suppression effect by employing small channel width as shown in Fig. 4.

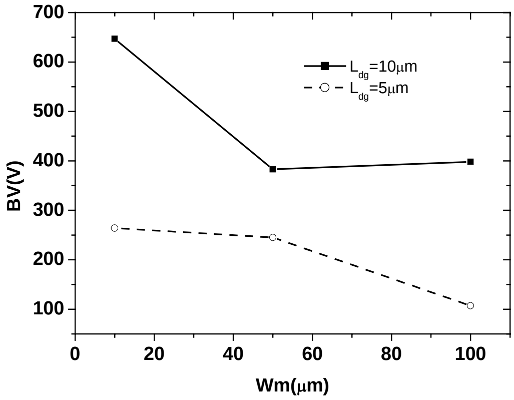


Fig. 5. Breakdown voltage as a function of various L_{gd} and Wm

Fig. 5 shows breakdown voltage as a function of Wm in two devices of which L_{gd} are 5μm and 10μm. All device shows high breakdown voltage due to employing Pt Schottky metal gate. Sufficient length design between gate and drain is required for high breakdown voltage as shown in experimental result. Larger breakdown voltage was measured in the device employing multi channel structure and long L_{gd} was effective for high breakdown voltage. Very high breakdown voltage of 640V in 10μm multi channel device was measured.

4. Conclusions

We have proposed multi channel design on mesa structure in order to reduce the two terminal gate-drain leakage current and increase breakdown voltage. Experimental results show that the leakage current is reduced effectively lower than half of conventional device and breakdown voltage is increased considerably without any additional process. Very high breakdown voltage of 640V in the proposed multi channel device was measured.

References

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