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Investigations on the Dynamic On-Resistance of High Voltage AlGaN/GaN HFETs

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Abstract

AlGaN/GaN HFETs with sufficiently larger thicknesses of undoped GaN channel improved dynamic on-state resistance. The role of undoped GaN channel in AlGaN/GaN HFETs was understood and better performed device was fabricated.

1. Introduction

AlGaN/GaN heterojunction field-effect transistors (HFET)s are considered as promising candidates for power switching due to their low on-resistance and high breakdown field.[1,2] However, the increase of dynamic on-state resistance, R_{ON}, immediately after off-state bias stress is often observed in AlGaN/GaN HFETs and regarded as the main obstacle of fast-switching operation of GaN HFET in spite of their very low gate charge. Several groups have been studied on the dynamic R_{ON}, and they mainly focused on the surface passivation and device design including field-plates. The GaN channel and buffer structure, however, could be very critical to dynamic R_{ON}, since the deep acceptors like carbon and iron in buffer are known to behave as electrical traps in GaN system.[3]

Here, we compare AlGaN/GaN HFETs with different thickness of undoped GaN channel. Although the DC characteristics of the HFETs show little variation, the dynamic R_{ON} of the HFETs is quite sensitive to the thickness of undoped GaN channel. From the experimental results, possible mechanism will be suggested

2. Experiments and discussions

Two AlGaN/GaN heterostructures with 50nm- and 200nm-undoped GaN channel were grown by metal-organic chemical vapor deposition (MOCVD). The undoped GaN channels were inserted between 25nm of $Al_{0.2}Ga_{0.8}N$ barrier and GaN:C buffer used for semi-insulating property, as presented in Figure 1.(a). The devices were fabricated as recessed metal-insulator-semiconductor (MIS) HFETs as described in Figure 1.(b).

Figure 2(a) shows the drain current (I_D) versus gate voltage (V_G) measured for the GaN recess MIS HFETs with 50 and 200 nm undoped GaN channel. The V_{TH} of 50nm sample is 1.3V and that of 200nm sample is 0.8V, and the current of 50nm sample and 200nm sample are 126mA/mm and 148mA/mm, respectively. The breakdown voltage of the 50nm sample and 200nm sample is 1230V and 1170V.(Figure 2.(b)). Although the 200nm device showed slightly lower V_{TH} and breakdown voltage, which might be due to thicker 2DEG, there is no significant difference in DC characteristics between the 50nm and 200nm undoped GaN channel.

In order to measure dynamic R_{ON}, we used a switching circuit (Figure 3(a)) which can control the stress voltage and drain current without any change of electric load. The measured switching frequency was 10kHz and the on-state gate voltage was 6V. While increasing V_{DD} from 0 to 200V, the dynamic R_{ON} was measured by 20V interval. The increase in dynamic R_{ON} is quantified as $R_{ON}(V_{DD})/R_{ON}(V_{DD}=0V)$. As shown in Figure 3.(b), the dynamic R_{ON} of 50nm sample is higher than that of 200nm sample for all V_{DD} region. Moreover, the dynamic R_{ON} of 50nm sample starts to increase at relatively low voltage (~20V), while that of 200nm sample starts to increase at about 80V of V_{DD}.

For understanding the suppressed dynamic R_{ON} of 200nm sample, schematic band diagrams were considered in each structure (Figure 4). Figure 4.(a) is a schematic band diagram of carbon-doped GaN buffer.[4] If positive voltage V_{DD} is applied to drain contact, the band structure would be bended like Figure 4.(b) and (c). The acceptor-traps come from carbon doping of 50nm-sample are immersed below Fermi-level in V_{DD} lower than 80V. In contrast, acceptor-traps of 200nm sample are not charged by electrons in same voltage condition. In addition, current collapse due to trapped charges in buffer could be stronger in 50nm sample than 200nm sample because of the short distance between 2DEG and the buffer. Consequently, the dynamic R_{ON} of 200nm sample increases at higher voltage (~80V) with suppressed slope.

3. Conclusions

In this paper, the effect of undoped-GaN channel on dynamic on-resistance was investigated and explained by band bending mechanism. It is remarkable that the switching performance is improved by the control of undoped GaN channel maintaining its DC characteristics.

References

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Figures

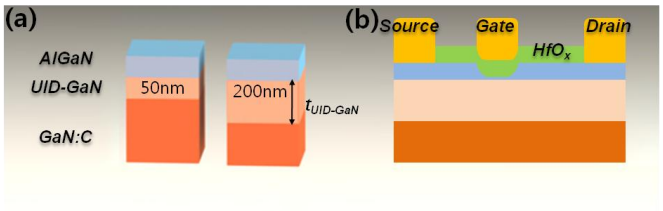

Figure 1. (a) AlGaN/GaN heterostructure having undoped GaN channel with thickness of 50nm and 200nm (b) Cross section of recessed MIS AlGaN/GaN HFET

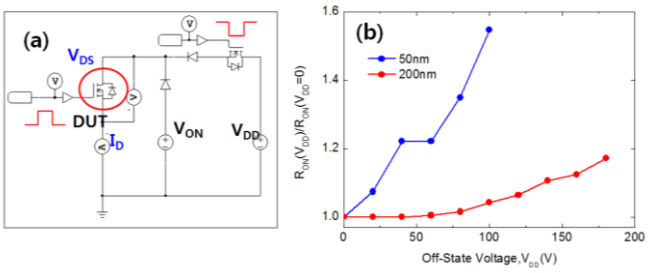

Figure3. (a) Switching circuit made for measurement of dynamic on-resistance (b) Dynamic on-resistance of 50nm sample and 200nm sample.

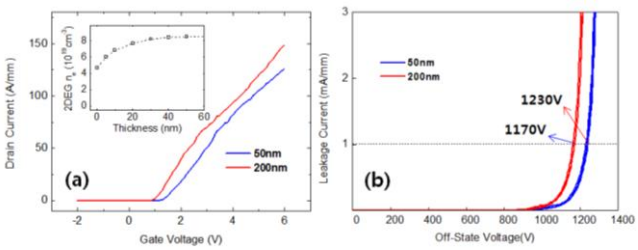

Figure 2. (a) I_D-V_G of 50nm and 200nm samples (b) Off-state leakage current. Breakdown voltage is determined at 1mA/mm.

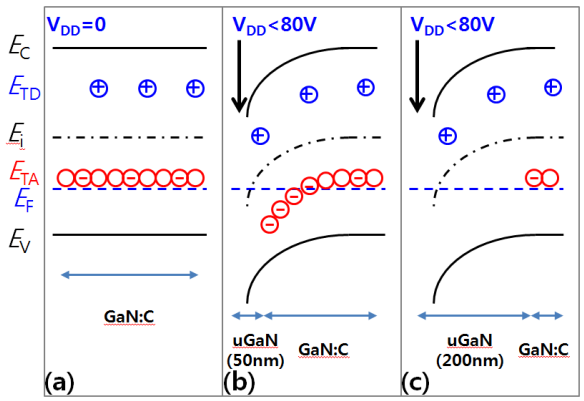

Figure4. (a) Schematic band diagram of carbon doped GaN buffer. (b) Schematic band diagram of 50nm sample bended due to positive voltage (V_{DD}<80V) applied to drain contact (c) Schematic band diagram of 200nm sample in the same condition.