Enhanced DC Characteristics of Si delta-doped AlGaN/GaN HFETs with p-GaN Backbarrier

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1. Introduction

AlGaN/GaN HFETs have been subject of intense investigation because of their potential for high power device application. In general, however, AlGaN/GaN HFETs suffer from the large drain leakage current caused by the difficulty in obtaining semi-insulating electrical buffer layer below the 2-DEG channel layer, especially when operating in high drain bias. Chang et al. have employed insertion of Mg-doped GaN layer underneath the channel layer to overcome this problem [1], resulted in improved drain leakage characteristics but reduced channel current due to carrier depletion from the field formed at pn junction.

In this study, we present the improved DC characteristics of AlGaN/GaN by adopting p-GaN backbarrier which reduces the drain leakage current and also introducing Si delta doping at the interface between GaN channel and p-GaN to increase sheet carrier density.

2. Experimental

We used two types of samples. Sample 1 has a conventional HFET structure. A 25 nm thick LT-GaN buffer layer was grown followed by the growth of a 2 um undoped highly resistive (HR)-GaN layer, a 100 nm undoped GaN layer (channel layer) and a 25 nm undoped $Al_{0.3}Ga_{0.7}N$ layer. Sample 2 was grown by utilizing a 1 um thick p-GaN layer instead of the HR undoped GaN and by using Si delta-doped layer directly before the channel growth.

Mesa isolation was performed by transformer coupled plasma-reactive ion etching (TCP-RIE) with BCl₃ and Cl₂ gas mixture. Ta/Ti/Al/Ni/Au layers were deposited using an electron beam (e-beam) evaporator, which was followed by rapid thermal annealing at 700 °C to form source/drain ohmic contacts. Ni/Au for gate metal was finally deposited by e-beam evaporater. The DC current-voltage characteristics of the HFETs were measured using an Agilent 4142B modular DC source/monitor and the Integrated Circuit Characterization and Analysis Program (IC-CAP). Schematic device cross sections for HFETs are shown in Fig. 1.

3. Results and Discussion

Table 1. shows carrier density (n_s) , mobility (μ) and $n_s\mu$ product for each sample by Hall measurement. Sample 2 shows a greatly increased carrier density with a decreased mobility compared to the value of conventional HFET structure. The decrease in mobility in such a high carrier

concentration is believed to be due to interface roughness scattering [2]. The Si delta-doped layer inserted between undoped GaN channel and p-GaN backbarrier would not only screen the electric field from the depletion region of the pn junction and hence prevent the channel from being depleted, but also acts as a back doping layer [3], which efficiently supplies electrons into the channel. These electrons are added to the polarization induced 2-DEG at the interface of AlGaN/GaN heterostructure.

Fig. 2 and Fig. 3 show the I-V characteristic and transfer characteristics of the samples. The maximum drain current and maximum transconductance of sample 2 was improved by 29 and 11 %, respectively.

Fig. 4 shows that the drain leakage current measured at V_D =10V was greatly reduced by adopting p-GaN backbarrier for at least two orders in magnitude, compared to the conventional heterostructure with HR undoped GaN buffer layer. This clearly indicates that the p-GaN back barrier is very effective as electrical buffer isolation layer.

Fig. 5 shows the reduction of gate leakage current. The leakage current of the HFET is caused by the reverse bias leakage current through the Schottky gate and the leakage current through the GaN buffer layer [4]. We also achieved a greatly reduced gate leakage current using p-GaN backbarrier structure and improved the carrier confinement.

4. Conclusions

In this paper we present the improved DC characteristics using Si delta-doped AlGaN/GaN HFET with p-GaN backbarrier. We achieved not only higher value of I_D and g_m but also lower value of drain and gate leakage current, by employing both the p-GaN backbarrier for reducing the drain leakage current and Si delta-doped layer for compensating the carrier depletion and hence increasing the sheet carrier density.

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< HFET with backbarrier >





Fig. 2 I_D - V_D characteristics of each sample



Fig. 3 Transconductance characteristics of each sample



Fig. 4 Drain leakage current of each sample



Fig. 5 Gate leakage current of each sample

	Carrier Density (n_s) [/cm ²]	Mobility (µ) [cm ² /Vs]	$n_s\mu$ product [(Vs) ⁻¹]
Si delta-doped HFET with p-GaN layer	1.2E13	1160	1.39E16
Conventional HFET	3.8E13	488	1.85E16

Table 1. Carrier density, mobility and $n_s \mu$ product