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AlGaN/GaN Power HEMTs Using Surface-Charge-Controlled Structure with Recessed Ohmic Technique

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1. Introduction

In the past several years, AlGaN/GaN HEMTs have attracted much interest for high power applications and there are a lot of papers related to the high output power characteristics.

It is generally recognized that we have to suppress frequency dependent characteristics such as current collapse and transconductance dispersion to obtain higher microwave performances.

Recently, we have overcome this problem by using "Surface-Charge-Controlled (SCC)" structure (n-GaN cap layer on AlGaN/GaN HEMTs), in which polarization-induced surface charge is controlled by n-type doping concentration in n-GaN cap [1], [2].

In this structure, however, it is difficult to reduce contact resistance due to its band diagram. As shown in Fig. 1, the conduction band profile in the near surface region directly determines ohmic contact.

In this paper, we proposed and demonstrated cap-removed ohmic structure to achieve low resistance contacts in SCC-structure and applied this method to AlGaN/GaN power HEMTs.

2. Experimental Procedure

The layer used in this study was grown by metal-organic chemical vapor deposition (MOCVD). The structure of the AlGaN/GaN HEMTs consisted of n-GaN/n-AlGaN/i-AlGaN/i-GaN/S.I.-SiC (Fig. 2). Cl_2 reactive ion etching (RIE) was applied to all of the samples for ohmic process.

Source/drain and gate electrodes were Ti/Al and Ni/Au, respectively. Ti/Al ohmic electrode was annealed at 550℃ for 30 s in N_2 ambient. We selected relatively low anneal temperature to keep surface of ohmic electrodes smooth. Typical gate length is 0.9 μm. After forming gate electrode, SiN was deposited on n-GaN cap layer as surface passivation. Then, Au air-bridge processes were used to form AlGaN/GaN power HEMT.

3. Results and Discussion

Figure 3 shows etching depth dependence on specific contact resistance for SCC-structure. The Al content in the AlGaN layer was 29 %. Specific contact resistance decreased from 9.80 x 10^{-4} Ωcm^2 for conventional structure to 2.56 x 10^{-5} Ωcm^2. These results mean that removing n-GaN cap layer enhanced tunneling transport of electron.

Figure 4 shows specific contact resistance as a function of Al mole fraction. Low ohmic contacts were achieved with low Al mole fraction. This is mainly attributed to decrease to Schottky barrier height, verifying that interface between metal and AlGaN is still important even after dry etching.

Next, we applied this ohmic structure to AlGaN/GaN power HEMTs and investigated device characteristics.

The Al content in the AlGaN layer was 25 %. On-wafer DC and RF measurements were performed. The maximum drain current, off-state gate-drain breakdown voltage and transconductance were 520 mA/mm, over 160 V and 200 S/mm, respectively (Fig. 5). No current collapse was observed under extremely high 100 V operation with good pinched-off characteristic.

For microwave performance, we carried out on-wafer load pull measurements at drain bias voltage of 12 V and deep lass AB operation at frequency of 1.9 GHz. The contact resistance determines R_{on}, which affects efficiency especially under "low" V_{ds} operation in power performance.

As shown in Fig. 6, we obtained P_{sat} of 31.1 dBm with the peak power added efficiency (PAE) of 55.6 % and a linear gain of 18.3 dB for a 1 mm gate-periphery AlGaN/GaN HEMTs. High PAE obtained even at low V_{ds}. These excellent results are mainly attributed to the improved ohmic contact and the suppression of current collapse by combing cap-removed ohmic structure and SCC-structure.

4. Conclusions

In summary, we demonstrated cap-removed advanced ohmic structure and achieved low specific contact resistance even using GaN-cap layer.

We confirmed that SCC-AlGaN/GaN HEMTs with cap-removed ohmic structure showed good ohmic characteristics, resulting in excellent DC, RF and power performance.

References

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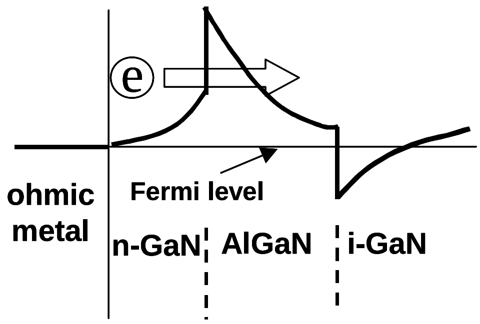

Fig.1Conduction band diagram just under an ohmic electrode of Surface-Charge-Controlled (SCC) structure with conventional ohmic structure.

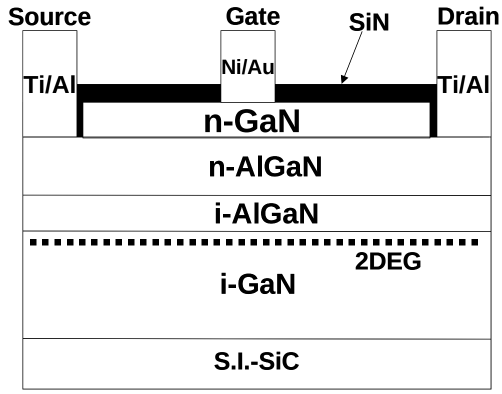

Fig. 2 Schematic drawing of investigated SCC-structure with cap-removed ohmic structure.

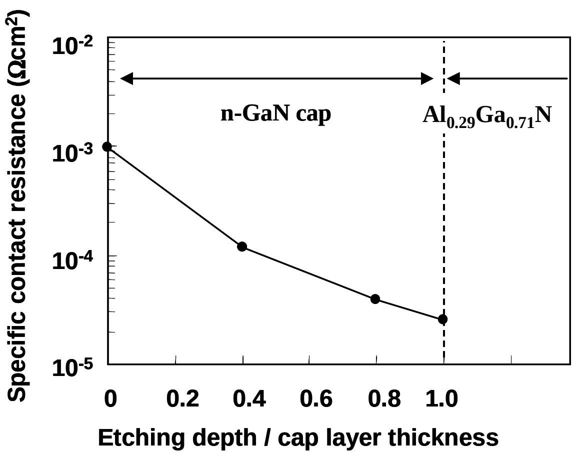

Fig. 3 Etching depth dependence of specific contact resistance.

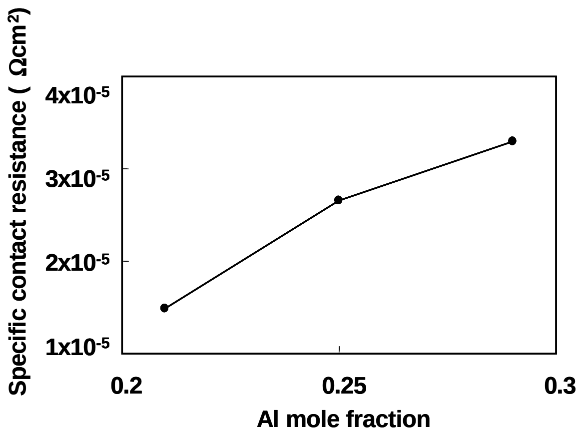

Fig. 4 Specific contact resistance as a function of Al mole fraction with cap-removed ohmic structure.

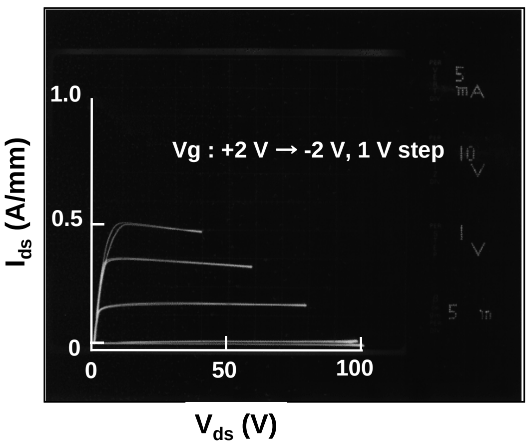

Fig. 5 I-V characteristics of investigated AlGaN/GaN HEMTs.

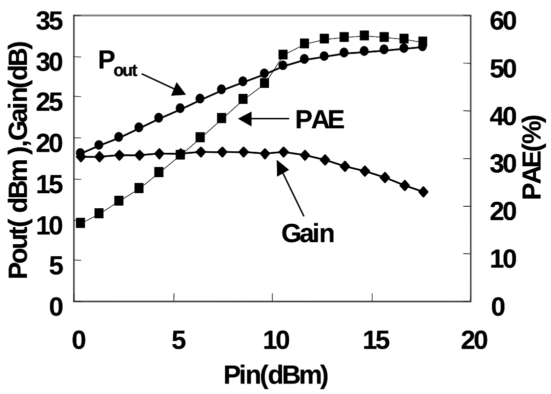

Fig. 6 RF performance of 1mm-AlGaN/GaN HEMTs at Vds=12 V.