# 6A-Operating Current GaN-Based Enhancement-Mode High Electron Mobility Transistors

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## Abstract

**This paper demonstrates an enhancement-mode (E-mode) GaN based high electron mobility transistors (HEMT) with a P-type layer on the Si substrate. The E-mode device is realized by growing a P-type layer on top of the AlGaN/GaN epistructure. We first characterized device performance based on a small gate-width device and then the high current mutli-finger gate power devices were demonstrated. The threshold voltage ($V_{th}$) of the device is 1.5 V. And the saturation drain of power devices can be operated up to 6.42 A.**

## INTRODUCTION

The GaN HEMT is a promising device in the category of power electrical devices. The two-dimentional electron gas (2-DEG) exists in the interface of GaN because of the built-in polarization electric field caused by the contact between AlGaN and GaN [1]. There-fore, 2-DEG produces high electron mobility in AlGaN/GaN HEMTs [2]. In addition, GaN is a kind of wide-band-gap material [3]. Therefore it can sustain high voltage efficiently. AlGaN/GaN HEMTs with high breakdown voltage and large current become a novel candidate for power electrical devices.

In this work, E-mode HEMTs are fabricated as small devices and power devices [4]. The small device is a single field-effect transistor (FET) structure, shown in Fig. 1. The p-GaN etching control of E-mode HEMT has been discussed in our previous research [5]. Figure 2 is the actual picture of the power device. The power device is parallel thirty-finger FET structure and total width is 45 mm. Threshold voltage of them is 1.5 V. We conclude with an E-mode GaN HEMT power device with a large drain current of 6.42 A and a large gate voltage of 8 V.

## DEVICE FABRICATION

E-mode HEMTs were grown on a Si substrate by metal organic chemical vapor deposition (MOCVD) and were composed of a 2.4 µm buffer, a 1.2 µm GaN, a 10 nm $ln_{0.25}Ga_{0.75}N$ barrier, and a 60nm p-type GaN layer with $Mg^{+}$ doping concentration of $5\times10^{19}cm^{-3}$. First, we defined mesa as isolation by ICP, and etched the p-GaN layer to define the position of the electrodes. Second, the Ti/Al/Ni/Au (25nm/150nm/50nm/125nm) was deposited as source/drain metal by E-gun, followed by annealing to reach ohmic contact with AlGaN. Then, Ni/Au (25nm/1000nm) was deposited as gate metal, and Benzocyclobutene (BCB) was used as the passivation layer. After via etching, the interconnecting metal Ni/Au (25nm/1200nm) was deposited to make the metal layer thicker.

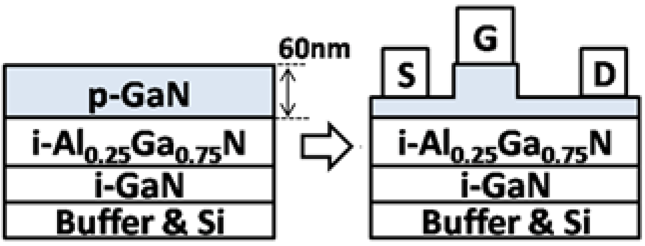

Figure 1 Fabrication procedures

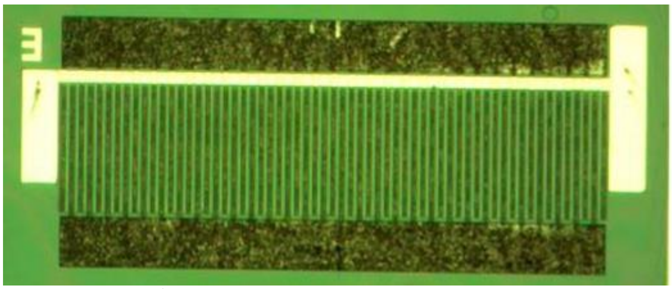

Figure 2 Picture of the power device

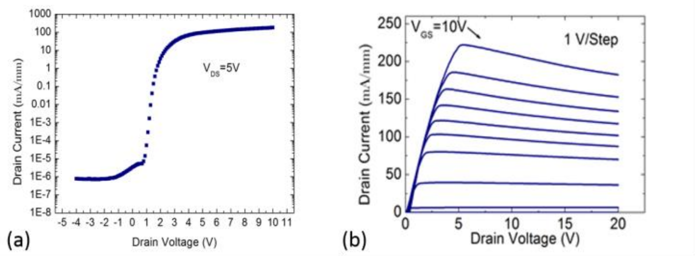

Figure 3 (a) Transfer characteristics of small devices (b) Output characteristics of small devices

## RESULTS AND DISCUSSION

At first, small devices are fabricated. Its gate-source length ($L_{GS}$), gate length ($L_{G}$), gate-drain length ($L_{GD}$), and gate width is 2, 4, 6, and 50 µm, respectively. The transfer curve of small devices is shown in Fig. 3 (a) and the threshold voltage ($V_{th}$) of it is a value of 1.5 V. For analysis easily, the threshold voltage, $V_{th}$, is defined that the bias of gate is at a drain current of 1 mA/mm when $V_{DS}$ is 5 V. Besides, it can work in a large gate voltage of 10 V, shown in Fig. 3 (b).

Analysis of breakdown voltage has also been test. The breakdown voltage, $V_{BD}$, is defined that the $V_{DS}$ is at a drain current of 1 mA/mm when the HEMT is at off-state. The small device has a high breakdown voltage of 1630 V with $L_{GD}$ = 16 $\mu$ m, shown in fig. 4 (a). In Fig. 4 (b), it is observed that the breakdown voltage is higher with longer $L_{GD}$.

The power device is a parallel thirty-finger structure. Each finger's gate-source length, gate length, and gate-drain length is 3, 4, and 10 μm, respectively. The total width is 45 mm. The transfer characteristic which is shown in Fig. 5, is similar with small device. In Fig. 6, the power device has a higher saturation current of 6.42 A when $V_{GS}$ is 8 V.

## CONCLUSIONS

In this research, we present an E-mode AlGaN/GaN HEMT with a heavily-doped p-GaN cap layer as power devices which can provide nice characteristics. The power device can still work even when $V_{GS}$ is over 8 V. The E-mode HEMT with a saturation current of 6.42 A is achieved. According to above advantages, the application of power devices with E-mode HEMT can be expected.

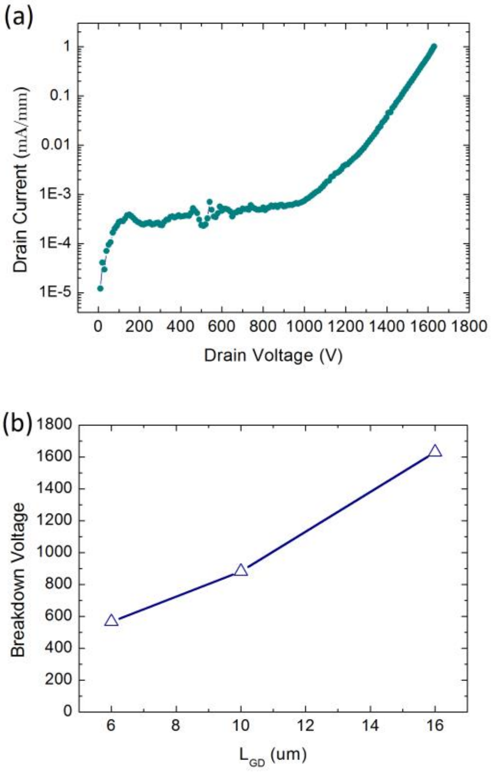

Figure 4 (a) Breakdown characteristic of small devices with $L_{GD}$ = 16 μm at $V_{GS}$ = 0 V. (b) Breakdown voltages of small devices with various $L_{GD}$.

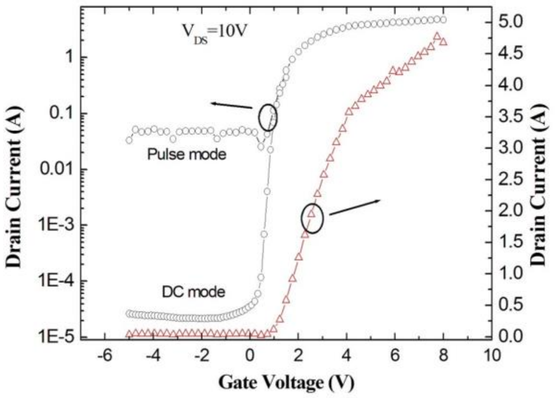

Figure 5 Transfer characteristics of power devices. The drain current is expressed in logarithmic (left) and linear (right) scale.

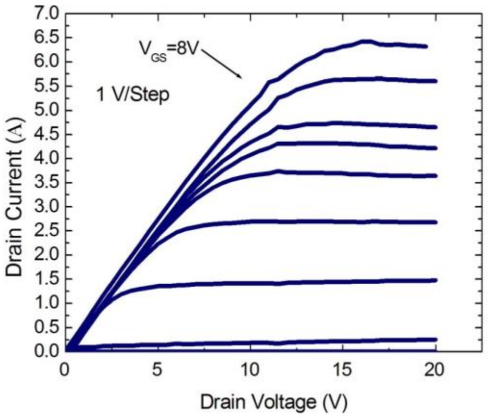

Figure 6 Output characteristics of power devices

## ACKNOWLEDGEMENTS

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