

# High-Power and High-Gain S-band AlGaN/GaN HFETs with Source Field Plates on Si Substrate

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## 1. Introduction

AlGaN/GaN heterojunction field-effect transistors (HFETs) have been widely investigated for high-frequency and high-power applications such as base stations of cellular phones, taking advantages of the superior material properties. Higher gain is also required in such applications, which reduces the number of amplifiers leading to smaller system in size. Introduction of field plate structures in the HFETs increases the gain by reducing gate-drain feedback capacitances ( $C_{gd}$ ) [1]. However, there has been a limitation of increasing the maximum output power keeping the high gain in the reported devices. In this paper, we present 203W output power with high gain of 16.9dB at 2.5GHz in AlGaN/GaN HFETs on Si substrates with source field plates. The detailed simulation using the device parameters at various biasing conditions reveals that shortening the field plate length achieves high output power together with the high gain, which well agrees with the experimental results.

## 2. Device Fabrication and Extraction of Device Parameters

AlGaN/GaN HFETs are grown on highly resistive Si substrate by metal organic chemical vapor deposition (MOCVD). The schematic cross section and the scanning electron microscopic (SEM) image of the fabricated device is shown in Fig.1 and Fig.2, respectively. The fabricated device typically exhibits maximum the drain current of 850 mA/mm, the on-state resistance of 4.0Ωmm and the gate-drain breakdown voltage of 180V. Epitaxial growth and processing technologies are fully established to serve high power operation free from the current collapse and other technical issues. In order to design the field plates, device parameters for the equivalent circuit shown in Fig.3 are extracted from the small signal RF performances at various biasing conditions.

## 3. Simulated and Experimental Power Performances

Large signal RF performances are simulated for the HFETs with various field plate lengths ( $L_{fp}$ ) using the extracted device parameters considering the variation of the parameters by the voltages. Fig.4 shows the simulated performances for the HFETs with the gate width of 0.8mm in which the output power with the 3dB suppressed gain from the linear value is defined as the maximum output power. The simulated and measured values of the linear gain together with the maximum output power are plotted

for various  $L_{fp}$ s. The measured values well agree with the simulated ones, where the highest output power is achieved at the  $L_{fp}$  of 0.6μm keeping high linear gain. The extracted gate-drain ( $C_{gd}$ ) and source-drain ( $C_{ds,fp}$ ) capacitances are summarized in Fig.5 and Fig.6, respectively. The feed-back capacitance  $C_{gd}$  is reduced by the field plates, which increases linear gain. The variation of the  $C_{ds}$  is significant for longer field plates, which causes the variation of output impedance so that the output power is reduced for the longer field plates. The gate width is extended to 48mm to increase the maximum output power, of which the  $P_{in}$ - $P_{out}$  characteristics are shown in Fig.7. High linear gain of 16.9dB is maintained up to the Pin of 24dB resulting in maximum output power of 203W at 2.5GHz for the CW operations. Very high PAE of 64% is also confirmed as a result of the increased gain. The state-of-the-art linear gains for the AlGaN/GaN HFETs are summarized in Fig.8 [2-4]. This is the first demonstration of high gain over 16dB in 200W-class AlGaN/GaN power HFETs on Si to the best of our knowledge.

## 4. Conclusions

We demonstrate high power AlGaN/GaN HFETs on Si with output power of 203W with the linear gain of 16.9dB operated at 2.5GHz. Device parameters are extracted from the small signal RF performances and they are applied for the large signal simulations. The simulated performances well agree with the measured ones indicating that the optimized  $L_{fp}$  of 0.6μm exhibits highest output power with high gain. The presented AlGaN/GaN HFET is very promising for the cellular base stations taking advantages of the good performances on low cost Si substrates.

## Acknowledgements

The authors would like to thank Mr. S. Kohda and Dr. Y. Yamada for their technical support on the epitaxial growth. They also would like to express sincere thanks to Mr.K.Yahata, Mr.T.Uno and other members of Advanced Device Development Center, Panasonic Corporation, for their help on the characterization of the RF performances.

## References

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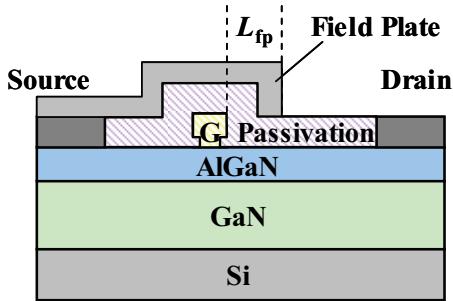


Fig.1 A schematic cross section of the fabricated AlGaN/GaN HFET on Si substrate with a source field plate

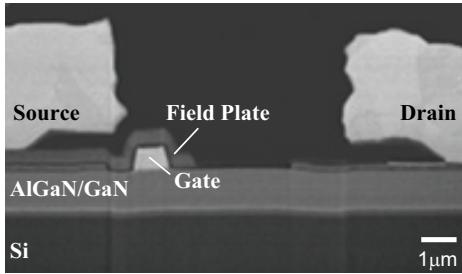


Fig.2 Cross sectional SEM image of the fabricated AlGaN/GaN HFET on Si with source field plates. The gate length ( $L_g$ ) and the gate-drain spacing ( $L_{gd}$ ) are 0.6μm and 3.0μm, respectively.

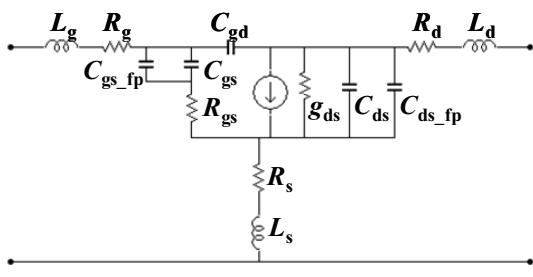


Fig.3 An equivalent circuit of AlGaN/GaN HFET for the simulation of the RF performances

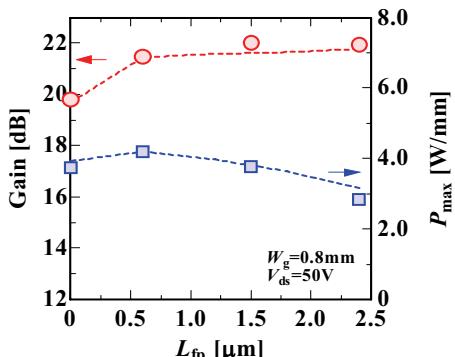


Fig.4 Linear gain and output power ( $P_{\max}$ ) of AlGaN/GaN HFETs plotted as a function of  $L_{fp}$ . The measured values are plotted using dots, while the simulated values are shown using dashed lines.

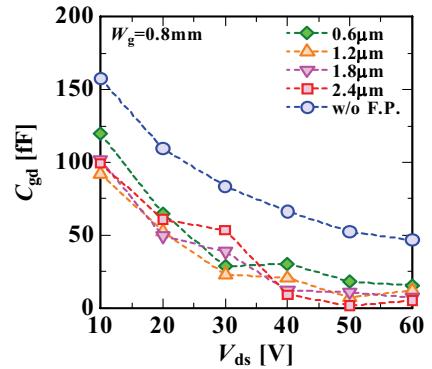


Fig.5 Extracted  $C_{gd}$  of the fabricated AlGaN/GaN HFETs with field plates for various  $V_{ds}$

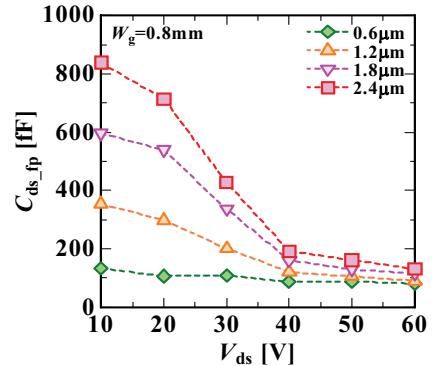


Fig.6 Extracted  $C_{ds\_fp}$  of the fabricated AlGaN/GaN HFETs with field plates for various  $V_{ds}$

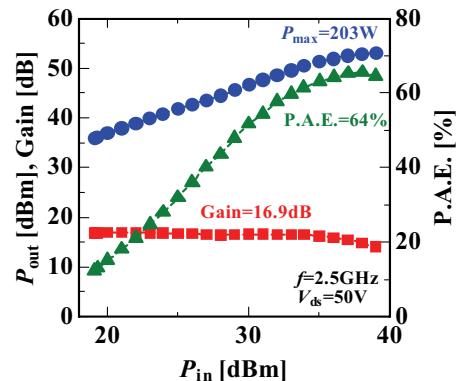


Fig.7  $P_{in}$ - $P_{out}$  characteristics of the AlGaN/GaN HFET with a gate width of 48mm. The maximum output power is 203W for the CW operation.

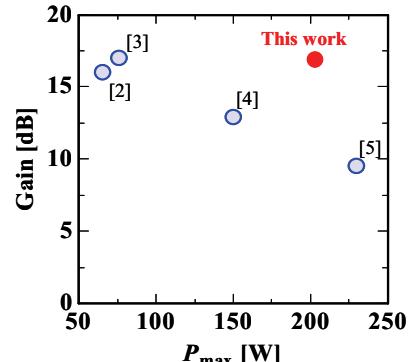


Fig.8 State-of-the-art performances of the AlGaN/GaN HFETs. The 203W output with the linear gain of 16.9dB is the best performance ever reported.