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Highly-Reliable GaN HEMT Transmitter Amplifier with Output Power of Over 200 W for Wireless Base Station

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1. INTRODUCTION

In this paper, we will describe the recent progress of GaN high electron mobility transistors (HEMTs) for 3G-wireless base station applications.

There are several reports relating to their high output-power characteristics. However, because of instability related to current collapse [1-4], only a few studies have demonstrated high-efficiency using large gate-periphery devices with a drain bias voltage (Vds) of over 50 V.

Base station systems also require extremely efficient amplifiers. We therefore need to ensure that the quiescent bias current is low. Low distortion characteristics near class-B operation are required when using digital modulation schemes such as IMT-2000. An adaptive digital pre-distortion (DPD) system, which was developed for practical W-CDMA base station amplifiers, controls a pre-distorted input signal into the power amplifier that cancels out the nonlinearity of the power amplifier. Thus, the AlGaN/GaN HEMT amplifier should be embedded in the DPD system. In addition, higher gain over 12 dB for a power amplifier over 100 W is needed for the system.

As a Fujitsu achievement, we will describe a state-of-the-art 250-W AlGaN/GaN-HEMTs push-pull transmitter amplifier with a high gain of 12.9dB that operates at a drain bias voltage of 50 V. The amplifier, combined with the DPD system, has also achieved an adjacent channel leakage power ratio (ACLR) of less than -50 dBc for 4-carrier W-CDMA signals with a drain supply voltage of 50 V.

Additionally, reliability and large-diameter substrate must be considered for mass-production. We therefore also will demonstrate a stable operation under RF stress testing for 1000 h at a drain bias voltage of 60 V. Highly uniform GaN-HEMT on a 3-inch S.I-SiC substrate was also fabricated.

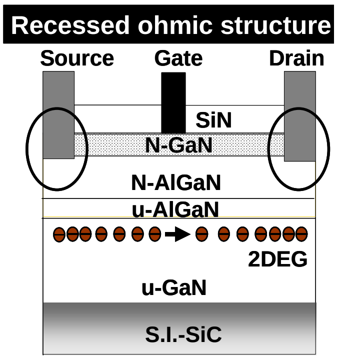

Fig. 1. Schematic cross-sectional view of AlGaN/GaN HEMT with surface-charge-controlled n-GaN-cap structure.

2. EXPERIMENTAL

To suppress instability related to large-signal current collapse and gm dispersion, we used an n-type doped GaN cap layer in the AlGaN/GaN HEMTs and controlled polarization-induced surface charges. Figure 1 shows the structures investigated in this study. We call this structure a "surface-charge-controlled" structure. Details of the fabrication method have been described previously [5]. Recessed ohmic technology was used to reduce ohmic contact resistance [6].

The current-collapse-free surface-charge-controlled AlGaN/GaN HEMT die was mounted on a conventional metal/ceramic package. The gate periphery was 36 mm with a unit gate width of 400 μm, as shown in Fig. 2. The single-chip amplifier was designed for application in a W–CDMA base station with a frequency of 2.1 GHz. The quiescent drain current (Idsq) was 1.4% Imax near class B, which is mainly used in base station systems. The push-pull amplifier consisted of two 36-mm AlGaN/GaN HEMTs.

3. RESULTS and DISCUSSIONS

When compared with a conventional structure, the surface-charge-controlled structure reduced the excessively high electric field on the drain side of the gate electrode [3]. The n-type doping and the thickness of the GaN cap layer were also optimized. As a result, residual current collapse did not occur in the AlGaN/GaN HEMT even at high drain bias voltages of up to 50 V, as shown in Fig. 3 [2,3].

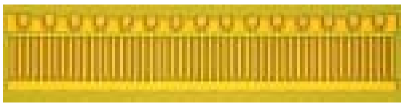

Fig. 2. Photograph of AlGaN/GaN HEMT chip. Total gate width is 36 mm with a unit gate width of 400 μm.

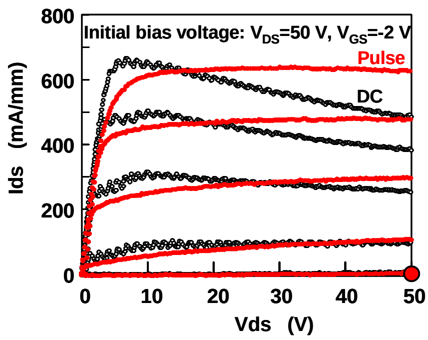

Fig. 3. DC and Pulsed I-V characteristics. Bias point of pulsed measurements was Vds of 50 V and Vgs of –2 V. Pulse period and pulse duration are 1 ms and 1 μs, respectively.

A 36-mm gate periphery AlGaN/GaN HEMT exhibited the high CW output power of 150 W with a high power-added efficiency (PAE) of 54% and a linear gain of 12.9 dB at a drain supply voltage of 63 V (Fig. 4). In a practical 4-carrier W-CDMA modulation scheme, a saturated peak power of 174 W with an ACLR of less than –52 dBc and a record drain efficiency of 40%[2] was achieved. The push-pull amplifier, combined with the DPD system, demonstrated a high efficiency of 37% and a peak power of 250 W with an ACLR of less than –50 dBc for W-CDMA signals with a drain supply voltage of 50 V (Fig. 5) [3]. A state-of-the-art high gain of 14.5 dB for a 116 W GaN-HEMT was also achieved on a SiC substrate (Fig. 6).

RF-stress measurements under CW P3dB at a Vds of 60 V showed stable output power for up to 1000 h (Fig. 7) [3,7].

We also fabricated GaN-HEMT on a 3-inch S.I.-SiC substrate. Standard deviation of 34 mV was typically obtained across an entire wafer (Fig. 8).

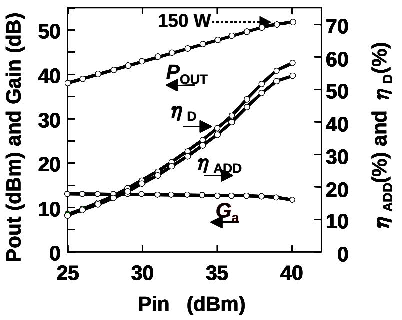

Fig. 4. Measurement of a 150 W CW power of single-chip AlGaN/GaN HEMT amplifier at 2.1 GHz. Quiescent drain current was 500 mA at Vds=63 V.

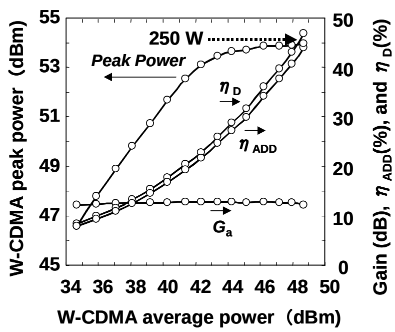

Fig. 5. Power characteristics of a 250 W push-pull amplifier at W-CDMA modulation scheme of Vds=50 V.

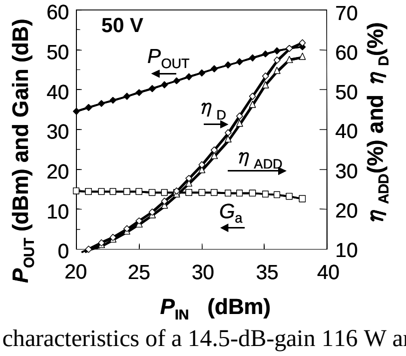

Fig. 6. Power characteristics of a 14.5-dB-gain 116 W amplifier.

4. SUMMARY

We conclude that an AlGaN/GaN HEMTs amplifier could fulfill the requirements of 3G W-CDMA systems for the first time. The benchmark focusing on a linear gain and the power trend of GaN-HEMTs amplifiers are shown in Fig. 9. Highly reliable GaN-HEMT capable of over 200 W will be cost effective solutions for IMT-2000 high-efficiency power amplifiers.

Acknowledgement

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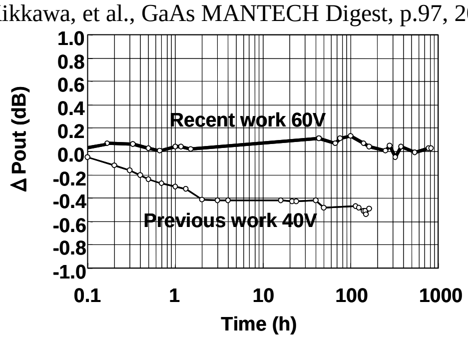

Fig. 7. Power characteristics under P3dB RF-stress test at 30, 40, and 60 V.

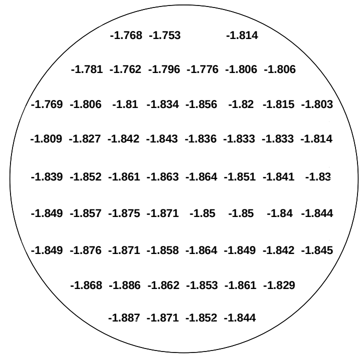

Fig. 8.Vth Distribution of GaN-HEMT fabricated on a 3-inch S.I.-SiC substrate. Standard deviation was 34 mV.

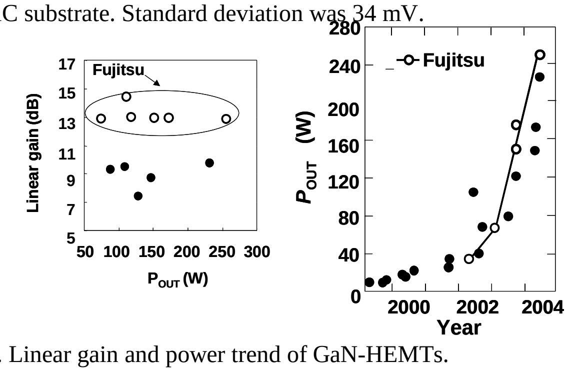

Fig. 9. Linear gain and power trend of GaN-HEMTs.