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RF Power Performance of AlGaN/GaN HJFETs

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1. Introduction

AlGaN/GaN heterojunction field effect transistors (FETs) are attracting much attention for microwave high-power application because of their high breakdown voltage, high carrier carrying capability and high saturation velocity. AlGaN/GaN FETs have typically been fabricated on a sapphire substrate and a SiC substrate. Sapphire substrates are available with low cost and diameters up to 8 inches. However their thermal conductivity (0.42 W/cm-K) is low as compared with that of SiC substrates (3.4 W/cm-K). On the sapphire substrates, 4.6 W/mm power density for a 150 μm-wide device [4], and 7.6 W CW power for a 6 mm-wide device were reported. On the SiC substrates, 9.1W/mm power density for a 100 μm-wide device [1], 22.9 W CW power for a 4mm-wide hybrid-matched device [2], and 51 W pulsed power for 8 mm-wide MMIC [3] were reported. Relatively inferior power performance of the device on a sapphire substrate is due to the lower thermal conductivity of sapphire.

In this paper, improved power performance of AlGaN/GaN FET on a thinned sapphire substrate is reported.

2. Device structure and fabrication

A cross section of the fabricated FET is shown in Fig. 1. An undoped AlGaN/GaN heterostructure was grown by metal organic chemical vapor deposition (MOCVD) on a 330 μm-thick (0001) sapphire substrate. Ti/Al ohmic electrodes were evaporated and alloyed at 650 °C. 0.9 μm-long Ni/Au gate electrodes were formed using optical lithography process. A standard Au-plated air-bridge process was used to fabricate multi-fingered FETs. Finally, the sapphire substrates were mechanically polished and the substrate thickness was reduced from 330 to 50μm.

3. Device Performance and Discussion

Current-voltage characteristics for 50 and 330 μm thick FETs are shown in Fig.2. No degradation in DC characteristics was observed after the polishing process. 40 μm-wide device exhibited a maximum drain current of 450 mA/mm and maximum transconductance of 70 mS/mm. The threshold voltage was typically -6 V. The two-terminal

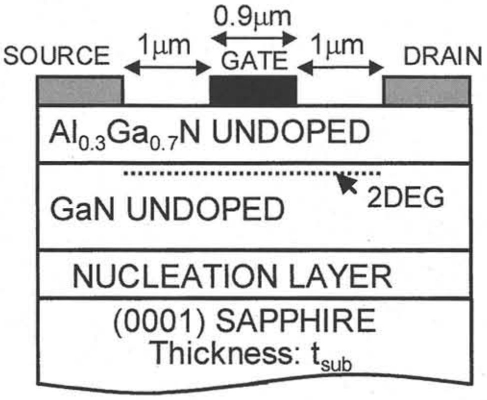

Fig. 1. Cross section of fabricated AlGaN/GaN FET

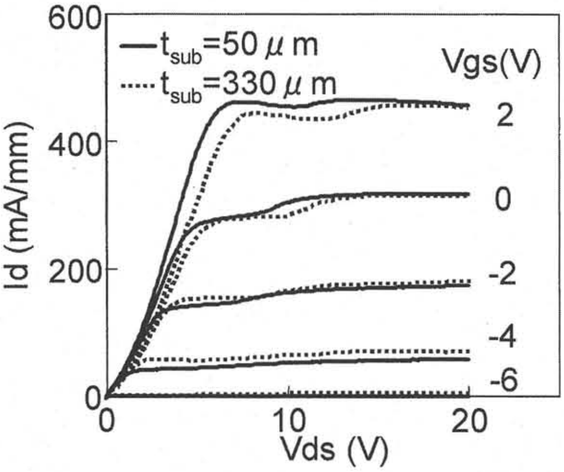

Fig. 2. I-V characteristics of 40 μm-wide FETs for t_{sub}=50 μm (solid) and 330 μm (dotted).

gate-drain breakdown voltage was typically 100V.

Small-signal characteristics for a 100 μm-wide device were evaluated by on-wafer S-parameter measurements from 0.5 to 40 GHz. A unity current gain cutoff frequency of 10 GHz and maximum oscillation frequency of 40 GHz were obtained with a 0.9 μm-gate length.

Large-signal characteristics for 1mm-wide devices with 50 and 330 μm-thick were evaluated with an on-wafer load-pull system. Figure 3 shows drain bias dependence of saturated power at 1.95 GHz. The 50 μm-thick device exhibited a CW saturated output power of 1.4-1.5 W/mm with 21 dB linear gain and 40 % power-added efficiency at 40 V drain bias. This output power is approximately 25 % higher than that of a 330μm-thick device (1.1-1.2 W/mm).

A 16 mm-wide device on 50 μm-thick sapphire substrate was packaged into a ceramic carrier and measured with a load-pull system. Figure 4 shows output characteristics at Vds = 34 V. 15.9 W CW (1.0 W/mm) saturated output power, 9.0 dB liner gain, and 29.1 % PAE were measured at 1.95 GHz. To our best knowledge, 15.9 W output power is the highest achieved for GaN FETs on sapphire substrates.

4. Conclusion

AlGaN/GaN FET on a thinned sapphire substrate with improved power capability has been demonstrated. A 16 mm-wide device exhibited a record output power of 15.9 W on a sapphire substrate.

Acknowledgments

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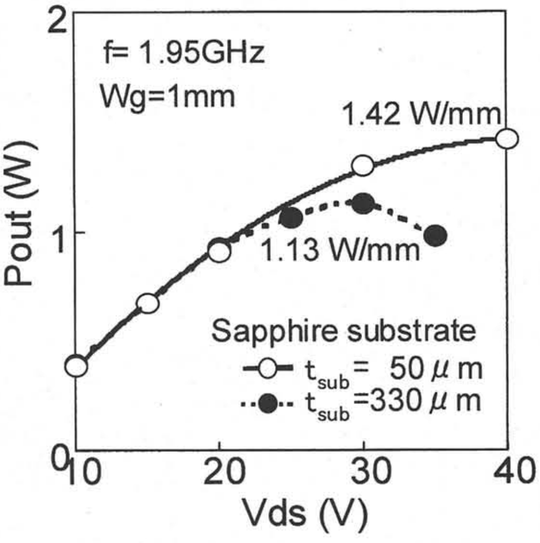

Fig. 3. Drain bias dependence of saturated power at 1.95 GHz for 1mm-wide FETs for t_{sub}=50 μm (open) and 330 μm (closed).

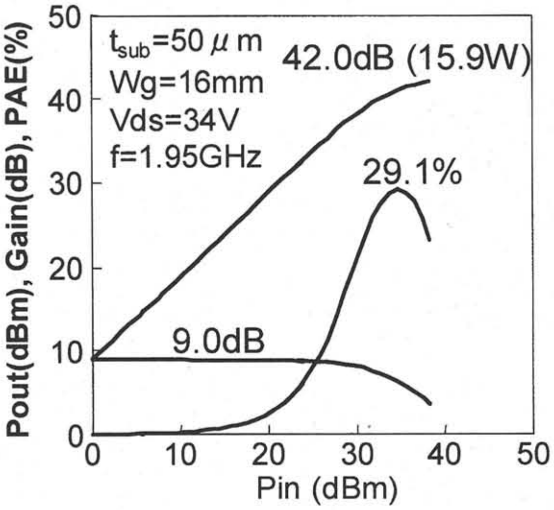

Fig. 4. 1.95 GHz power sweep for 16 mm-wide FET (t_{sub}=50 μm, Vds=34V).