Extended Abstracts of the 2004 International Conference on Solid State Devices and Materials, Tokyo, 2004, pp. 662-663

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Pulsed IVT Characteristics of AlGaN/GaN HEMT on the Isothermal Conditions

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1. Introduction

Wide band-gap devices have received much attention for high-frequency and high-power applications. Among them, AlGaN/GaN HEMTs have great potential, because of the material advantages such as high breakdown voltage, high electron mobility and high electron density [1]. But there are still some issues on AlGaN/GaN HEMTs, such as current collapse (power slump), self-heating effect and power scaling with the device size scaling. And there are only a few studies on the self-heating effect considering the bias power condition [2].

So in this paper, we have studied the self-heating effect using pulsed IV and IVT measurement in 'the same bias power condition' - isothermal condition.

2. Epi-structure and Process of AlGaN/GaN HEMT

The devices were fabricated on an $Al_{0.3}GaN$ /GaN heterostructure grown by MOCVD on a sapphire substrate. The structure is shown in Fig.1. The 2DEG mobility and sheet carrier density were 1180cm^2/Vs and 9.1x10^{12}cm^{-2} at R.T. The device was isolated by ICP RIE etching using Cl_2. The Ohmic contacts were formed by Ti/Al/Ta /Au(200Å/800Å/350Å/1000Å) and alloying at 850°C for 30sec in N_2 ambient. 0.5μm T-gate -defined by E-beam lithography- was formed by Pd/Mo/Ti/Au (50Å/200Å/200Å/4500Å) evaporation and the conventional lift-off process. And 600Å Si_3N_4 film was deposited using RPECVD with N_2 plasma pre-treatment [3]. The gate width was 2×200μm and source-to-drain, gate-to-gate spacing were 4μm, 50μm. The device had V_{TH}=-5.6V, $G_{M.MAX}$=187mS/mm, I_{DSS}=646mA/mm, BV_{GD}=68V and f_T=11GHz, f_{MAX}=32GHz at V_{GS}=-5V, V_{DS}=10V. (Fig.2.)

3. Measurements of the Pulsed IV & IVT Characteristics

For pulsed IV(IVT) measurements, we used synchronized gate and drain pulse on the some bias point (using Accent-Diva). Its method is described Fig.3. In our devices, pulsed IV characteristics at V_{GS} near V_{TH} did not show drain current reduction. But as the gate bias voltage (V_{GS}) became higher than V_{TH} and the drain bias voltage (V_{DS}) became higher than 0V, the drain current was reduced and V_{KNEE} was increased at pulsed IV characteristics. It could be the current collapse caused by surface trap.[4]

We analyzed the pulsed IV characteristics using 'the same bias power condition.' The same bias power condition meant the several bias points which have the same (drain bias current) × (drain voltage). Because the pulsed IV characteristic was measured at other bias points with the same bias power condition using short pulse (500ns pulse-width) and log pulse separation (1ms separation), it could be thought to be on isothermal conditions of the device operation.

The pulsed IV characteristics under same bias power condition with different bias points had small difference. The drain current at the pulsed IV characteristics was decreased and V_{KNEE} was increased as in Fig. 4. (a).

For more detailed analysis, we measured pulsed IVT characteristics under 35~120°C ambient temperatures. The pulsed IV characteristic's tendency of ambient temperature increasing was similar to that of the bias power increasing under the room temperature as shown Fig.4.and Fig.5.

So Fig.4 could show how the self-heating affects the AlGaN/GaN HEMT's operation. It could be thought that one of the important reasons of the power slump problem of the GaN based HEMT using the sapphire substrate and the power scaling difficulty with the device size scaling, was the thermal problem caused by the self-heating effect.

Fig. 1. Schematic of AlGaN/GaN HEMT epi structure

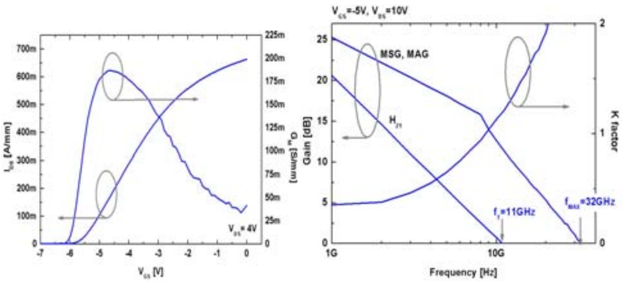


Fig. 2. DC transconductance & RF characteristics

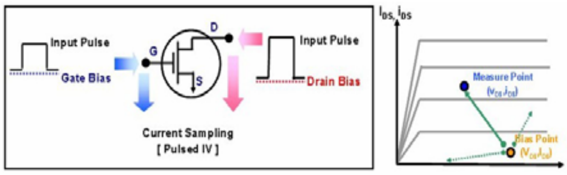
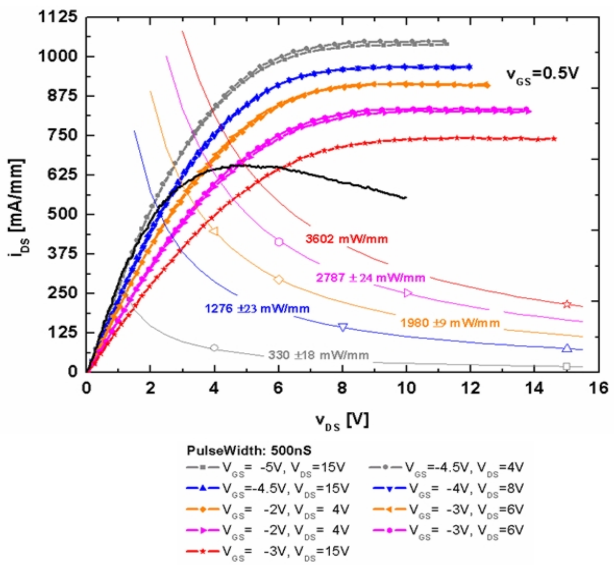
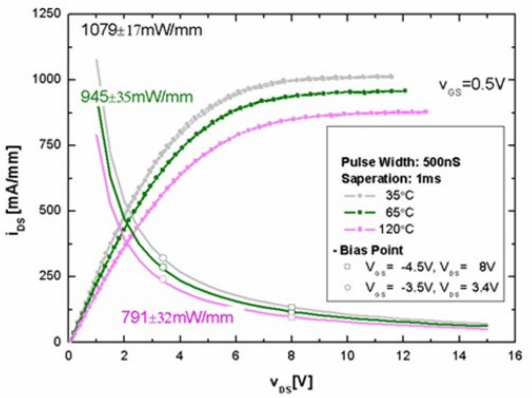


Fig. 3. Pulsed IV Measurement

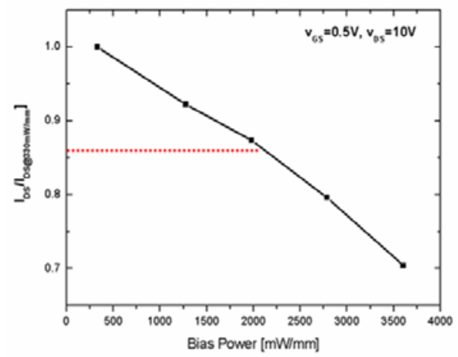


(a) Pulsed IV Characteristics at R.T.(20°C)

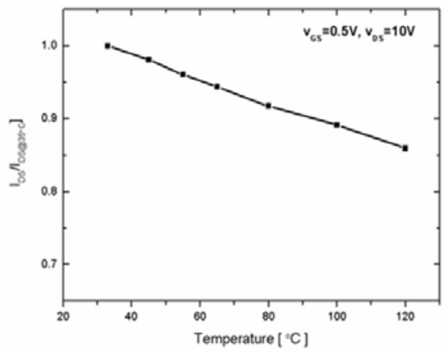


(b) Pulsed IVT characteristics

Fig. 4. Pulsed IV-(a) & Pulsed IVT-(b) Characteristics with the same bias power conditions



(a) Normalized by pulsed IV characteristics at 339mW/mm bias condition



(b) Normalized by pulsed IVT characteristics at 35°C ambient condition

Fig. 5. Normalized Pulsed IV-(a) and Pulsed IVT-(b) Characteristics with the same bias power conditions

4. Conclusions

In this paper, we studied the self-heating effect of AlGaN/GaN HEMT using pulsed IV and IVT characteristics on isothermal condition. And it showed how the self-heating affects the AlGaN/GaN HEMT's operation. It could be thought that one of the important reasons of the power slump problem of the GaN based HEMT using the sapphire substrate and the power scaling difficulty with the device size scaling, was the thermal problem causing by the self-heating effect.

Acknowledgements

This works was financially supported by the RRC program of the Minister of Science & Technology under the Millimeter-wave Research Laboratory. The authors would like to thank Dr. Lorraine B. McGuire for epitaxial growth of AlGaN/GaN HEMT's layer

References

[1] Mitsutoshi Akita, et al. August 2001 *IEEE EDL* Vol. 22, No.8, pp. 376~377

[2] Likun Shen, et al. *DRC 2003* pp.63~64

[3] Tamotsu Hashizume, et al. Jul/Aug *2003 J.Vac.Sci.Technol*.B 21(4) pp.1828~1838

[4] Vetury, R. et al. March 2001 *IEEE Trans. on ED* Vol.48, No.3 pp.560~566.