High Transconductance AlGaN/ GaN HEMT Growth on Sapphire Substrates

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Abstract: The fabrication and characterization of AlGaN/GaN high electron mobility transistors (HEMT) grown on sapphire substrates by MBE are described. These 1.0-μm gate length devices exhibit a maximum drain current density as high as 1000mA/mm and a maximum transconductance of 198mS/mm. In sharp contrast to high current density HEMT fabricated on sapphire substrates, the extrinsic transconductance versus gate-source voltage profiles exhibit the broad plateaus over a large voltage swing. A unity gain cutoff frequency \( (f_T) \) of 18.7GHz and a maximum frequency of oscillation \( (f_{\text{max}}) \) of 19.1GHz are also obtained.

Key words: AlGaN/GaN, high electron mobility transistors, transconductance

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1 Introduction

AlGaN/GaN high electron mobility transistors (HEMT) are promising devices for high power, high temperature, and high frequency applications. This potential is due to the advantageous material properties. GaN itself possesses a wide band gap of 3.4eV, a very high breakdown field (3MV/cm), and an extremely high peak velocity \( (3 \times 10^7 \text{cm/s}) \) and saturation velocity \( (1.5 \times 10^7 \text{cm/s}) \)[1]. In addition, AlGaN/GaN heterostructures with high conduction band offset and high piezoelectricity will result in high sheet carrier density in the \( 1.0 \times 10^{13} \text{cm}^{-2} \) range. Coupling this high sheet carrier density with the high breakdown field of GaN yields predictions of microwave power densities greater than 10W/mm at 10GHz.

In recent years, tremendous progress has been made in the material quality and device processing of GaN-based HEMTs, which has resulted in significant improvement in the DC and RF performances of these devices. MOCVD-grown 0.25μm gate-length AlGaN/GaN HEMT with drain current density as high as 1.4A/mm, transconductance of 400mS/mm, and an \( f_T \) of 85GHz and \( f_{\text{max}} \) of 151GHz has been demonstrated[2]. The best reported result of AlGaN/GaN HEMT in China was \( g_m \) of 157mS/mm, \( f_T \) of 12GHz with gate length of 0.25μm[3].

In this paper, we report MBE-grown AlGaN/GaN HEMT. A maximum extrinsic transconductance of 198mS/mm was obtained, which is the highest reported transconductance in China. These devices exhibited a maximum drain current density of 1000mA/mm, \( f_T \) and \( f_{\text{max}} \) of 18.7 and 19.1GHz, respectively. These results represent a significant improvement in the AlGaN/GaN-based HEMTs grown on sapphire substrates[4].

2 Device structure and fabrication

The schematic cross-sectional structure of AlGaN/GaN HEMT is shown in Fig. 1. The het-
3 Device performance

The DC characteristics were measured by HP4155A semiconductor parameter analyzer. The typical drain current-voltage ($I_{DS}$ $V_{DS}$) characteristics of a device are shown in Fig. 2. The HEMT was fabricated with a source-drain spacing of 4μm and gate length of 1.0μm. The gate width was 80μm. The gate was biased from 1V to −6V in the step of −1V. The device exhibited a maximum drain current density of 1000mA/mm at a gate bias of 1V and a drain bias of 7.4V. The drop in drain current at higher bias is attributed to the self-heating because of the poor thermal conductivity of sapphire substrates.

In Fig. 3, the drain current and transconductance are plotted against gate bias voltage. It is obvious that this device has reached a maximum extrinsic transconductance of 198mS/mm at $V_{DS} = −3.3V$, the drain was biased at 5V. An important feature to note is the extrinsic transconductance versus gate-drain-source voltage profiles exhibits the broad plateaus over a large voltage swing.

In Fig. 4, the drain-to-source currents are plotted against gate bias voltage. It may be noted that the leakage current increases gradually with applied reverse bias. However, the leakage current is low, even at a bias of −10V. The reverse leakage current at the gate voltage of −4V is $8 \times 10^{-6}$A.

RF measurements were carried out on-wafer us-
available power gain (\( G_{\text{Am}} \)) of a HEMT with 4\( \mu \)m source-drain spacing and 1\( \mu \)m gate length, 100\( \mu \)m gate width. At a drain bias of 5V and a gate bias of \(-3V\), an \( f_T \) of 18.7GHz and an \( f_{\text{max}} \) of 19.1GHz were obtained.

4 Conclusion

In conclusion, AlGaN/GaN HEMTs are fabricated on sapphire substrates. These devices exhibit a high drain current and DC transconductance of 1000mA/mm and 198mS/mm, respectively. Our data show that a unity gain cutoff frequency (\( f_T \)) of 18.7GHz and a maximum frequency of oscillation (\( f_{\text{max}} \)) of 19.1GHz are available from these devices.

References


高跨导 AlGaN/ GaN HEMT 器件

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摘要：报道了生长在蓝宝石衬底上的 AlGaN/ GaN HEMT 器件的制造工艺以及在室温下器件的性能。器件的栅长为 1.0μm，源漏间距为 4.0μm。器件的最大电流密度达到 1000mA/mm，最大跨导高达 198mS/mm，转移特性曲线表现出增益带宽较宽的特点。同时由所测得的 S 参数推导出栅长为 1.0μm 器件的截止频率(f_T) 和最高振荡频率(f_m) 分别为 18.7GHz 和 19.1GHz。

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