High-Linearity High Current Drivability GaInP/GaAs MISFET using GaInP Airbridge Gate Structure Grown by GSMBE

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SUMMARY

A novel structure GaInP/GaAs MISFET with the undoped GaInP serving as the airbridge for gate metal to run over it between the active region and pad was designed and fabricated for high power and high frequency applications. Due to the GaInP airbridge gate structure, a high current drive, high breakdown, high linearity, high speed and low leakage gate current GaInP/GaAs MISFET was achieved.

1. INTRODUCTION

High linearity performance of an electronic device is very important for microwave power applications. A device with good linear characteristics can reduce the intermodulation of high frequency signals, and therefore the distortion of signals at high power level operation is suppressed. High electron mobility transistors (HEMTs) have demonstrated excellent performance in low noise applications. As for commercial high power applications, it is still dominated by MESFETs. It has been demonstrated that if a low-doped or undoped layer is placed between the metal gate and relatively high doped channel, the linearity of a device will be improved [1]. Therefore, we like to study the Metal-undoped GaInP-n GaAs MISFET. There are several advantages by using GaInP/GaAs material system: (1) the etching selectivity between GaInP and GaAs is very high and therefore the gate recess will automatically stop at the undoped GaInP layer. This will result in high uniformity and yield; (2) the reliability will be better since GaInP/GaAs contains no aluminum; (3) the breakdown voltage will be increased due to the undoped high band gap GaInP; (4) the undoped GaInP can also be used as the airbridge for the gate metal to run over it. The airbridge structure not only can reduce the gate to source capacitance and hence improve the speed of the device but also reduce the gate leakage current. Therefore, in this paper, we report the performance of the GaInP/GaAs MISFET using the GaInP airbridge structure.

The characteristics of GaInP/GaAs airbridge gate MISFET was evaluated by DC and RF testings. Due to the presence of undoped high E_g GaInP used for insulator and passivation layer, a wide and flat transconductance together with a high current density was achieved. Moreover, the airbridge technique based on etching away GaAs dielectric between the active region and gate pad, minimizes parasitic capacitances and leakage current are minimized. Thus RF responses are improved. These characteristics of high linearity, high current drivability and high speed suggest that GaInP/GaAs MISFET is suitable for high frequency power device applications.

2. DEVICE TECHNOLOGY

The GaInP/GaAs MISFET structure was grown by GSMBE with the following device parameters as shown in Fig.1: n active channel is doped to $6 \times 10^{17} \text{ cm}^{-3}$ with a thickness of 100nm, the GaInP is undoped with a thickness of 100nm, and the n+ GaAs cap layer is doped to $2 \times 10^{18} \text{ cm}^{-3}$ with a thickness of 40nm. The transistor was fabricated by traditional optical lithography and mesa type wet etching technique except for the formation of the GaInP airbridge, which is fabricated by selectively etching the GaAs layer underneath the GaInP. This means that the gate feeder, instead of contacting on the surface of the mesa edge, is lying on top of the GaInP airbridge between the active mesa region and gate pad. An illustrative figure is shown in Fig. 2.

n+ GaAs cap layer $2 \times 10^{18} \text{ cm}^{-3}$
undoped GaInP insulator layer 100nm
n GaAs channel $6 \times 10^{17} \text{ cm}^{-3}$ 100nm
GaAs buffer layer 500nm
S. I. GaAs

Fig.1 Layer structure of GaInP/GaAs MISFET Fig.2 Traditional mesa type FET and airbridge gate FET

3. RESULTS AND DISCUSSIONS

The common source current-voltage (I-V) characteristics of the finished device is shown in Fig. 3. As can be seen, excellent pinched-off characteristics and current drive capability of about 610 mA/mm were achieved. This value is much larger than the conventional MESFET (280 mA/mm) and MISFET (380 mA/mm) at the same gate-to-drain breakdown voltage [2], which means the GaInP/GaAs MISFET is suitable for power applications. By varying the V_{gs} with fixed $V_{ds} = 4\text{V}$, we get the I_{ds} v.s. g_m curve, as shown in the Fig. 4. Clearly, a very flat region of 390 mA/mm operational range is achieved for the g_m values above 100mA/mm, which means the linearity is very good and is comparable to the recently reported result (360mA/mm) [3]. Compared with the traditional MISFET, the airbridge gate MISFET also has much lower gate leakage current (about two orders of magnitude smaller) as shown in Fig. 5. This figure also exhibits a gate-to-drain breakdown voltage of 25V for airbridge gate structure, which will consequently benefit for device under large signal operation. The results of RF

which will consequently benefit for device under large signal operation. The results of RF measurements are shown in Fig. 6. From this figure, a cut-off frequency f_T of 22 GHz and maximum frequency of oscillation f_{max} of 40 GHz were achieved. Both value are near state of the art results for a GaAs FET with a gate length of $1\ \mu\text{m}$. The high values of f_T and f_{max} were attributed to the smaller gate to source capacitance due to the GaInP airbridge structure [4].

4. CONCLUSION

A high current drive, high breakdown, high linearity, high speed, and low leakage gate current GaInP/GaAs MISFET was achieved. All the excellent features were attributed to the GaInP airbridge gate structure.

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Fig.3 The common-source I-V characteristics

Fig.4 The characteristics of transconductance vs drain-source current

Fig.5 gate current vs gate voltage characteristics for traditional and airbridged gate MISFET

Fig.6 The RF characteristics of the fabricated device

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