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A Refractory WN_x/W Self-Aligned Gate GaAs Power MESFET for 1.9-GHz Digital Mobile Communication System Operating with a Single Low Voltage Supply

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We have developed a refractory WNx/W self-aligned gate GaAs power MESFET operating with high efficiency at a gate bias of 0 V and a small drain bias of 2.7 V. This power MESFET is quite promising for a highly efficient linear power amplifier IC operating with a single low voltage supply. A high power-added efficiency of 26.4 % was attained for $\pi/4$-shift QPSK modulated input signals in the 1.9-GHz band.

INTRODUCTION

In recent years, the field of mobile communications has greatly expanded to include L-band digital mobile radio systems. A 1.9-GHz personal handy phone system using $\pi/4$-shift QPSK (Quaternary Phase Shift Keying) modulation technique is being newly introduced in order to satisfy increasing demands for personal communication services in Japan. With the miniaturization of the mobile radio phone sets operated with low power dissipation at low voltage, power amplifier ICs have become the key components in the transmission blocks of the battery operated telephone sets. In addition to high efficiency and low voltage operation, the power amplifiers are required to operate with high linearity and low distortion in L-band digital mobile radio systems.

It was reported that gallium arsenide power MESFET amplifiers[1,2] have high gain and high efficiency capabilities in L-band, which are superior to Si power MOSFET amplifiers. Most of GaAs power amplifiers, however, require two voltage supplies, because conventional GaAs power MESFETs generally operate under negative gate bias conditions.

This paper describes a refractory WNx/W self-aligned gate GaAs power MESFET operating with high efficiency at a gate bias of 0 V and a small drain bias of 2.7 V. The power MESFET is quite promising for a highly efficient linear power amplifier ICs operating with a single low voltage supply, because of its small drain knee voltage, high transconductance and sufficient breakdown voltage.

DEVICE STRUCTURE AND FABRICATION

Figure 1 shows the schematic cross-sectional view of the refractory WNx/W self-aligned gate GaAs power MESFET. The power MESFET has a planar structure on an undoped semi-insulating 3-inch GaAs wafer, which is suited for monolithic ICs.

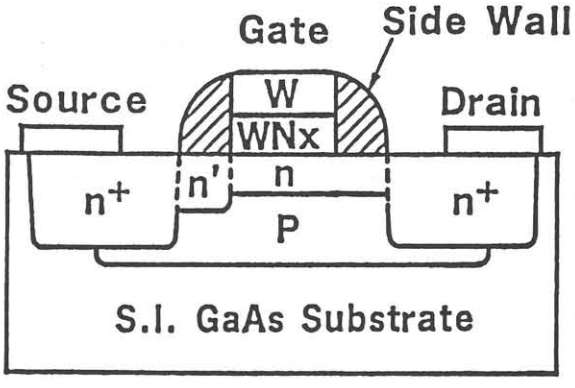


Fig.1 Schematic cross-sectional view of WNx/W self-aligned gate GaAs power MESFET.

A refractory gate technology is a promising approach for planar process because of good device reliability and long term stability. The WNx/W bilayer was employed to reduce gate resistance by 1/20, compared with WNx monolayer[3]. The 120-nm thick WNx and 300-nm thick W film were deposited by magnetron sputtering in Ar + N_2 mixed gas and in Ar gas, respectively. The stress of the W film was reduced by adjusting the Ar pressure during sputter-deposition. The gate pattern was formed using image reversal process with optical lithography and reactive ion etching with a CF_4 + O_2 mixed gas.

The power MESFET has an asymmetrical structure fabricated by fully ion-implanted process which is the most appropriate from the industrial viewpoint. The source-side region was self-aligned to the refractory WNx/W gate electrode, and the drain-side region was formed 0.3 μm off the gate, so that both low on-state resistance and sufficient breakdown voltage was realized. The n^+ and n' regions were formed by Si ion implantation at 110 keV and 45 keV, respectively. A thin n-channel layer was formed by Si ion implantation at 25 keV, and a buried p-layer was formed by Mg ion implantation at 180 keV to eliminate short channel effect. Furnace annealing process was performed at 820 °C in an AsH_3 + Ar atmosphere without any encapsulating film to activate implanted regions.

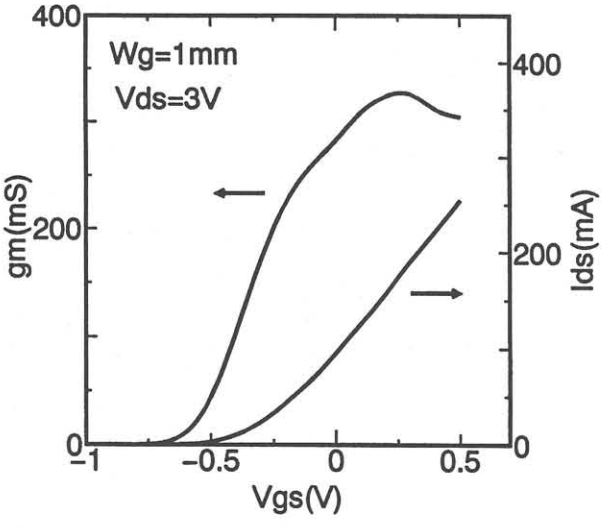


Fig.2 Typical drain current I_{ds} and transconductance g_m versus gate voltage V_{gs}.

DC CHARACTERISTICS

Figure 2 shows the typical drain current I_{ds} and transconductance g_m of the refractory WNx/W self-aligned gate GaAs power MESFET as a function of gate voltage V_{gs}, with respect to a drain voltage V_{ds} of 3 V. The gate length L_g and width W_g are 0.6 μm and 1 mm, respectively. A high transconductance of about 300 mS was obtained, which realizes good rf output power performance even at a gate bias of 0 V. A threshold voltage of more than -1 V was chosen to lower current dissipation. The maximum drain current I_{dsmax} was 0.25 A. A very small drain knee voltage of 0.6 V was attained at a gate bias V_{gs} of 0.5 V, which is essential for low drain voltage and high efficiency operation. A breakdown voltage of less than -6 V was obtained, which is sufficient for class AB operation.

1.9-GHz OUTPUT PERFORMANCE

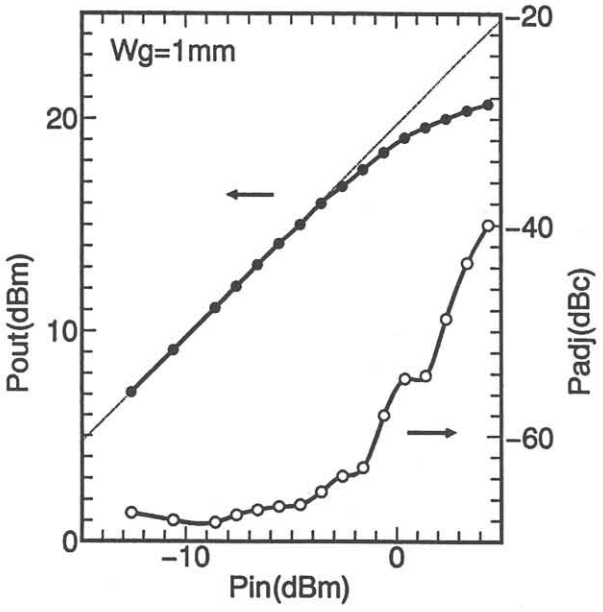
The output power performance of the refractory WNx/W self-aligned gate GaAs power MESFET for π/4-shift QPSK modulated input signals in the 1.9-GHz band were measured at a gate bias of 0 V. The power MESFET operated in a class AB bias condition under which the quiescent drain current was about 1/3 of I_{dsmax}. The load condition was tuned as the maximum output power at about 1-dB gain compression was obtained.

Figure 3(a) shows the output characteristics of the power MESFET at a drain bias V_{dd} of 2.7 V. An output power P_{out} of 18.4 dBm and a power gain of 19.0 dB were measured, when adjacent channel leakage power P_{adj} at 470 kHz apart from 1.9 GHz was -58 dBc. A high power-added efficiency of 26.4 % was attained. These results shows that the refractory WNx/W self-aligned gate GaAs power MESFET is suitable for 1.9-GHz Japanese personal handy phone system.

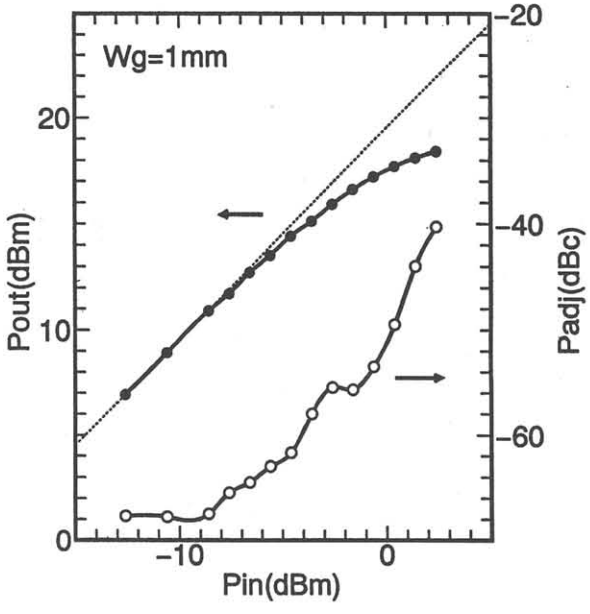
Figure 3(b) shows the output characteristics at a drain bias V_{dd} of 2.0 V. The power MESFET provided a power-added efficiency of 20.4 % when P_{adj} was -58 dBc.

CONCLUSION

A refractory WNx/W self-aligned gate GaAs power MESFET has been developed, which is suitable for a linear power amplifier IC operating with a single low voltage supply. The



(a) V_{dd} = 2.7 V



(b) V_{dd} = 2.0 V

Fig.3 Output power characteristics at a gate bias of 0 V for $\pi/4$-shift QPSK modulated input signals in the 1.9-GHz band. P_{adj} is an adjacent channel leakage power at 470 kHz apart from 1.9 GHz.
(P_{adj}[dBc] = P_{adj}[dBm] - P_{out}[dBm])

power MESFET has a planar, asymmetrical structure fabricated by fully ion-implanted process. It operated with high power-added efficiency of 26.4 % at a gate bias of 0 V and a low drain bias of 2.7 V for $\pi/4$-shift QPSK modulated input signals in the 1.9-GHz band due to its small drain knee voltage, high transconductance and sufficient breakdown voltage. The refractory WNx/W self-aligned gate GaAs power MESFET technology is one of the most promising candidates in realizing highly efficient L-band linear power amplifier ICs for use in next-generation digital mobile communication systems.

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