Pseudomorphic Inverted HEMT Suitable to Low Supplied Voltage Application

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ABSTRACT

The superiority of pseudomorphic inverted HEMT as a promising low-voltage-operating device was revealed. To study the high frequency properties of FET, two types of frequency variable measurement systems which represent active load and common-source circuits were employed. It was confirmed that the feature of low knee voltage in static I-V is preserved above 100kHz, which predicts the microwave characteristics of the device. Estimated output power was 50% higher than that of conventional pseudomorphic HEMT at V_{dd}=1V.

INTRODUCTION

Recently, demands for low-voltage-operating high-speed devices are growing rapidly[1,2], not only in digital application but also in analog/ microwave applications. Low voltage operation is indispensable to lower the power dissipation in applications for portable apparatus or to realize multi-cascoded circuits under battery power supply.

Among various devices, submicron gate HEMT is reported[3,4] to exhibit better characteristics under low supplied voltage, compared with GaAs MESFET or Si MOSFET. Lower knee voltage of HEMT structure is attributed to its high electron mobility and good 2-DEG confinement. In our previous paper[5], we have mentioned that pseudomorphic inverted HEMT (P-I-HEMT) is more promising for low supplied voltage operation. The drain current saturation property of P-I-HEMT is superior to conventional pseudomorphic HEMT (P-HEMT) because of its excellent confinement of 2-DEG[6].

On the other hand, many papers have revealed that I-V properties of FETs in RF are different from those in DC[7], and must be discussed in frequency region at least around 100kHz or 1MHz.

In this paper, we discuss the low voltage properties of P-I-HEMT in various frequency range and we show that the advantage of P-I-HEMT is maintained even in the RF. The measurement systems we employ here are to simulate two types of applications, switching transistor and active load transistor, in the frequency range up to MHz.

DEVICE DESCRIPTION

P-I-HEMT structure grown by MBE, shown in Fig.1, has pseudomorphic InGaAs channel layer on n-AlGaAs, opposite to conventional HEMT structure. The inner part of the stepped recess, formed by dry/wet etching, is filled with the 0.2µm-long mushroom-shaped gate.

Fig.2 shows static characteristics of P-I-HEMT and P-HEMT. Both devices are fabricated in the same process and in the same lot. P-I-HEMT shows better drain current saturation characteristics and lower knee voltage than P-HEMT. Fig.3 shows the g_d calculated from 0.5-12GHz S-parameters under constant I_d and the maximum of f_T in each V_d. P-I-HEMT has smaller g_d both in DC and RF, and has higher f_T at low drain voltage.

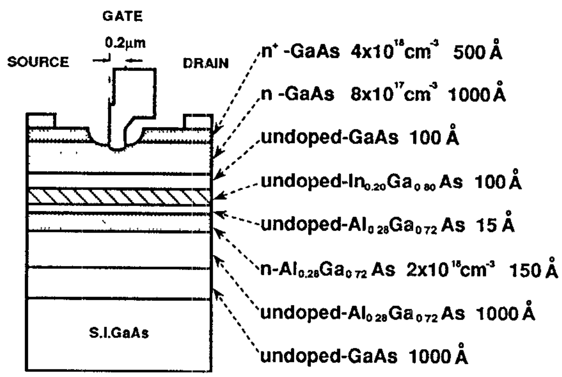

Fig.1 Schematic cross section of P-I-HEMT

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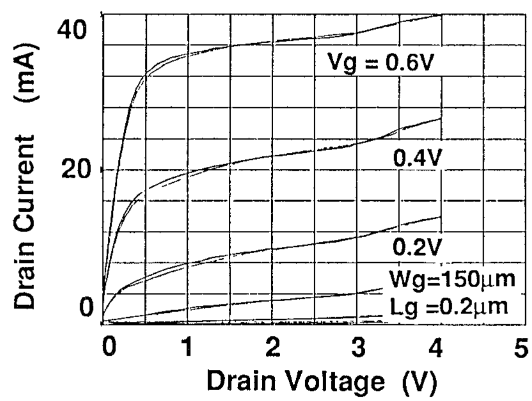
MEASUREMENT SYSTEMS

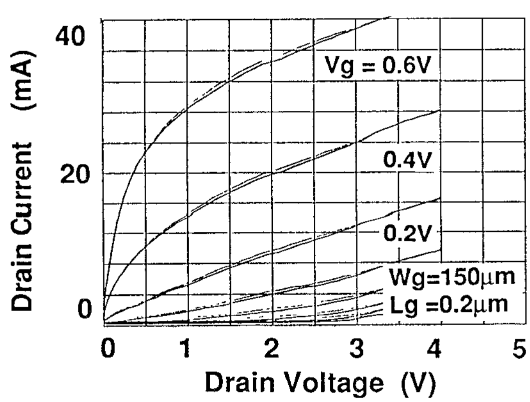
Most of compound semiconductor FETs are known to show drastic changes of their characteristics around 100Hz-10kHz: such changes are related to deep level traps and make the RF device parameters totally different from the DC ones. Consequently, parameters above 10kHz, instead of DC data, well represent RF characteristics. To understand large-signal behavior in RF, therefore, we construct two types of measurement systems.

Measurement system A is shown in Fig.4(a), where, drain voltage can be swung as large as 5Vp-p up to 100kHz under the constant gate voltage. I_d-V_d curves of FETs are obtained from the calculation of digitizing oscilloscope data. These I_d-V_d results are helpful to understand RF operation applied to active load and current source circuits.

In another system (system B: Fig.4(b)), trapezoidal voltage up to 1MHz is supplied to gate, and drain current is supplied through the load resistor. This configuration gives the load lines of FETs, which are useful to amplifier design.



(a)



(b)

Fig.2 Static characteristics of (a)P-I-HEMT and (b)P-HEMT

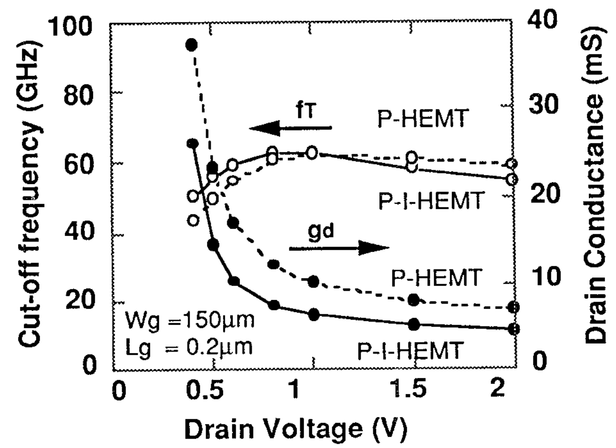
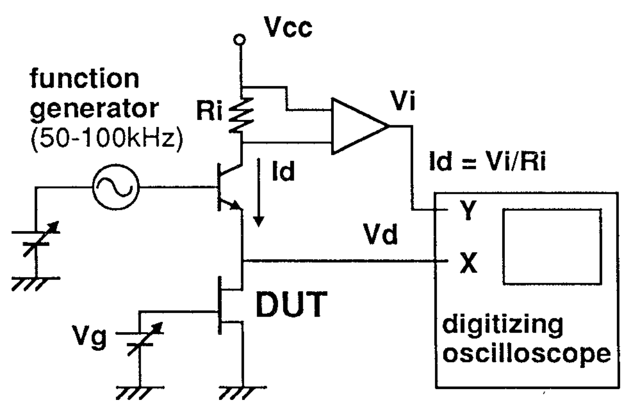
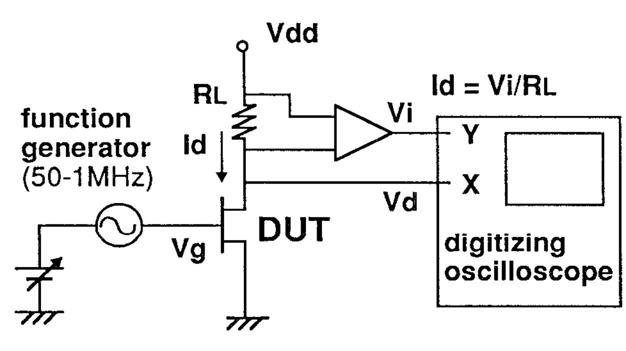


Fig.3 Cut-off frequency and drain conductance calculated from 0.5-12 GHz S-parameters



(a) Measurement System A



(b) Measurement System B

Fig.4 Measurement configuration

RESULTS AND DISCUSSION

Fig.5 shows results of P-I-HEMT measured by system A. In this figure, curves of 100kHz with the amplitude from 0V to 1, 2 and 4V are plotted with the static curve of [50Hz, 4V]. In the case of [100kHz, 4V], I_d decrease is serious in low V_d region. For smaller voltage swings of 1Vp-p, the I_d decrease almost disappears. The overlay plot I_d-V_d curves for 100kHz with 0.6V voltage swings around various bias points, are shown in Fig.6. The center of each curve is exactly on the 50Hz I-V curves, however, the fact that the gradient for 100kHz is larger shows the frequency dispersion of g_d even in the small swing around the operating points.

These results suggest that in the application of active load or current source circuit, frequency dispersion of g_d still remains even in the low supplied voltage conditions. However, when the voltage swing itself is small, the change in I_d is sufficiently suppressed.

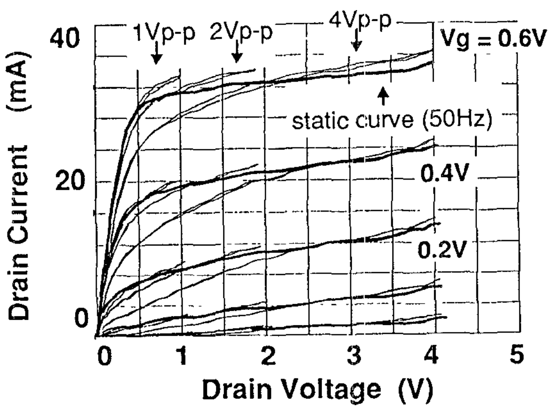


Fig.5 Large signal I-V characteristics at 50Hz and 100KHz

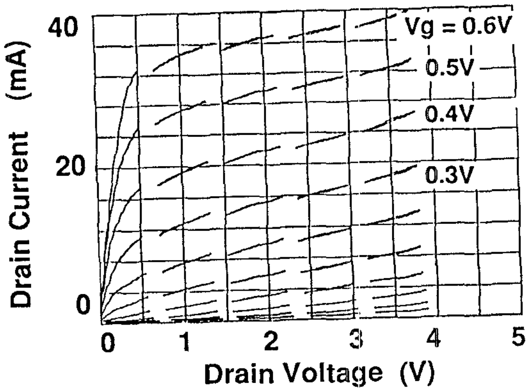


Fig.6 Multi bias points I-V characteristics at 100KHz

Fig.7(b) shows the result of P-I-HEMT measured by system B. Gate voltage is supplied from +0.6V to bellow pinch-off voltage at 1MHz. Several kinds of supplied voltages (0.5V to 5V step 0.5V) are applied, and several parallel load lines can be drawn. I-V curve (b) is obtained as an envelope of load line edges. Curve (a) is measured by system A at 100kHz, that is shown in Fig.5 (4Vp-p). Curve (c) is the static curve. Curve (a) and (b) coincide with curve (c) in low frequency. In curve (b) measured by system B, drain current I_d decreases in whole region but clear knee properties are not disappeared, that is almost parallel to the static curve(c). Drain conductance of curve (b) does not change so large compared with curve(a). In Fig.8, two kinds of load resistance (R_L=15Ω and 82Ω) are compared. The envelope of 82Ω load line edge shows rounded curve at the knee, whereas that of 15Ω load line has the clear knee. These results

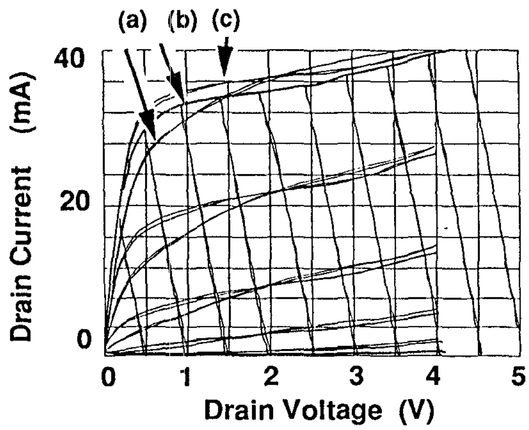


Fig.7 I-V curves for P-I-HEMT measured by (a) system A at 100kHz, (b) system B at1MHz, and (c) the static curve.

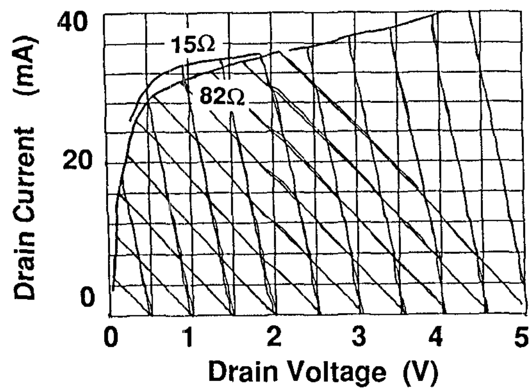


Fig.8 Comparison of envelopes in measurement system B with load resistor of 15Ω and 82Ω.

suggest that I-V curve property depends on frequency and also magnitude of gate voltage and/or drain voltage.

Fig.9 shows the relation between output power and supplied voltage at the frequencies of 50Hz and 1MHz. Output power is calculated from the power consumption of load resistor. Solid lines are for P-I-HEMT and dashed lines are for P-HEMT. For small R_L, the degree of output power decrease as supplied voltage (V_{dd}) decreases, is suppressed in P-I-HEMT compared with P-HEMT. For example, for V_{dd}=1V and R_L=15Ω, the power of P-I-HEMT is 50% larger than that of P-HEMT. Moreover, the frequency dispersion of power is small in the condition of low R_L and low V_{dd}. Large difference in power between 50Hz and 1MHz at V_{dd}>3V and R_L=82Ω is caused by the difference of I-V curve (shown in Fig.8).

From the result of the measurement with the system B, which represents the case of common-source power amplifier application, it is proved that frequency dispersion in power property is not serious for low supplied voltage operation. The excellent feature of low knee voltage in P-I-HEMT maintains even in the high frequency. The high output power of P-I-HEMT at low supplied voltage may be brought about by this low knee voltage.

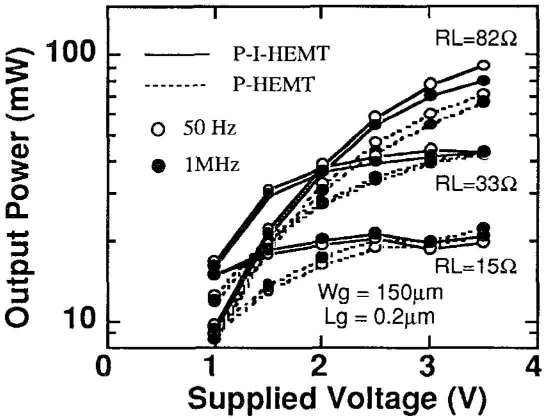


Fig.9 Comparison of output power vs. Vdd between P-I-HEMT and P-HEMT

CONCLUSION

In this paper, the properties of pseudomorphic inverted HEMT (P-I-HEMT) as a low-voltage-operating device is discussed. To study the high frequency properties of FET, two types of frequency variable measurement systems which represent active load and common-source circuits were employed.

It was confirmed that the feature of low knee voltage in static I-V of P-I-HEMT is preserved above 100kHz, which predicts the microwave characteristics of the device. Higher output power is obtained in P-I-HEMT than in P-HEMT at low supplied voltage. It is concluded that P-I-HEMT is one of the most promising devices which operates under the low supplied voltage.

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