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AlGaAs/GaAs/InGaAs Double-Doped Quantum-Well HEMTs for Low Distortion Amplifier

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We have successfully fabricated AlGaAs/GaAs/InGaAs Double-Doped Quantum-Well (DDQW) HEMTs with flat-gm characteristics in the wide gate voltage range from -1.0V to 0.3V. The feedback amplifier using this HEMT showed excellent low distortion properties of IP_2 and IP_3 of 59.4dBm and 40.0dBm, respectively, at 1GHz, and good noise figure of less than 2.0dB throughout a wide frequency range of 100MHz to 1.6GHz. These features will make the DDQW HEMTs quite suitable for low-distortion and low-noise amplifier applications.

1. Introduction

AlGaAs/GaAs HEMTs have demonstrated excellent low-noise and high-speed performances so far. From the view point of their applications to low-distortion linear ICs or microwave power devices, however, the strong dependence of their transconductance(gm) on the gate voltage must be improved[1]. With regard to MESFETs, flat-transconductance characteristics have been obtained using a graded channel[2] or a GaAs/InGaAs pseudomorphic heterostructure[3] so far. By analogy to these previous reports, we propose here a Double-Doped Quantum-Well (DDQW) structures to improve the linearity of HEMT device. The channel layer of this HEMT consists of a pseudomorphic InGaAs and a GaAs on top of it and is sandwiched by two N-AlGaAs electron supply layers. The DDQW HEMT has been found to show flat-transconductance in a wide gate voltage range. Using this HEMT, we have fabricated a negative feedback amplifier and evaluated its distortion characteristics.

n-GaAs	10nm
n-$Al_{0.2}Ga_{0.8}As$	25nm
u-$Al_{0.2}Ga_{0.8}As$	2nm
u-GaAs	20nm
u-$In_{0.2}Ga_{0.8}As$	10nm
u-$Al_{0.2}Ga_{0.8}As$	2nm
n-$Al_{0.2}Ga_{0.8}As$	10nm
u-$Al_{0.2}Ga_{0.8}As$	100nm
u-GaAs	350nm
S.I. GaAs Substrate	

Fig. 1 Schematic cross-sectional view of the AlGaAs/GaAs/InGaAs Double-Doped Quantum-Well (DDQW) HEMTs structure.

2. Device Fabrication

The epi structure of the AlGaAs/GaAs/InGaAs DDQW HEMT is shown in Fig.1. It was grown by solid-source MBE on a semi-insulating(100) GaAs substrate. The growth rate of each layer was about 0.5μ m /h. The growth of the structure was initiated with a 350nm-thick GaAs buffer layer and a 100nm-thick undoped AlGaAs layer grown at about 500°C. The quantum-well channel layer consists of a 10nm-thick undoped InGaAs and a 20nm-thick undoped GaAs on top of it. The channel layers were sandwiched by 25nm-thick N-AlGaAs barrier layer and10nm-thick N-AlGaAs carrier supply layer doped with Si to 2×10^{18} cm^{-3} via a 2nm-thick undoped AlGaAs spacer layer. Finally, 10nm-thick N-GaAs cap layer doped with Si to 2×10^{18} was grown on the AlGaAs barrier layer. The channel region was defined by mesa etching, and AuGe/Ni/Au and Ti/Pt/Au were used as

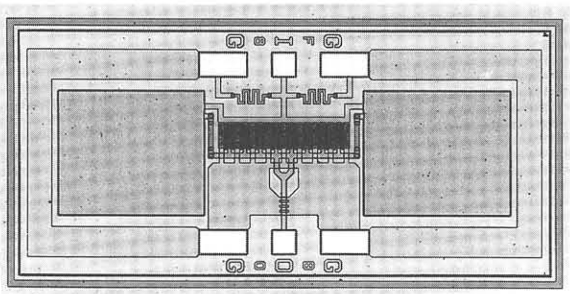

Fig. 2 Overview of a fabricated broadband feedback amplifier with two resistors using WSiN and a MIM capacitor together with a 800μm-gatewidth DDQW HEMT.

ohmic contacts and gate metals, respectively. The gate length was 0.7μ m with T-shaped gate structure. Fig.2 shows an overall view of a fabricated broadband feedback amplifier with resistors and a capacitor. It consists of two resistors using WSiN and a MIM capacitor together with a 800μm -gatewidth DDQW HEMT.

3. DC and RF performance

Fig.3 shows gm-Vgs characteristics of a DDQW HEMT with a gate width of 150μ m. It clearly shows a

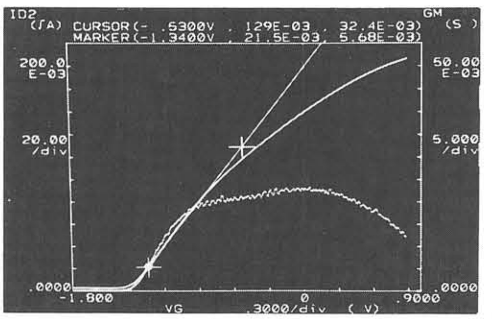

Fig. 3 Gm versus Vgs characteristics.

flat-gm characteristics in the wide gate voltage range of Vgs from -1.0V to 0.3V. The maximum transconductance (gm_{max}) was 150 mS/mm. S-parameters were measured from 1GHz to 20GHz using Cascade Microtech probes and a HP-8510 network analyzer. The current gain cut-off frequency f_T was 25GHz for the simple FET of the gate-length of 0.7μ m and the gate width of 800μ m, respectively.

Fig.4 shows the circuit diagram of the fabricated negative feedback broadband amplifier. The circuit in the

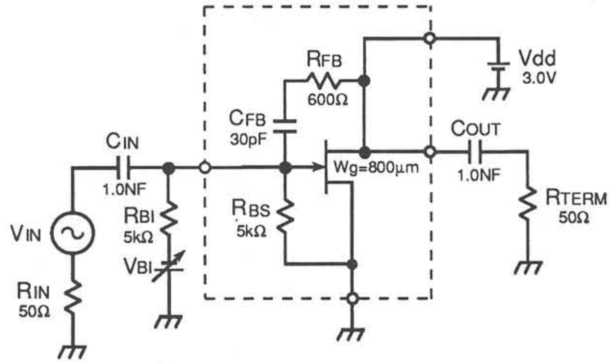

Fig. 4 The circuit diagram of the fabricated negative feedback broadband amplifier.

dashed square is integrated in one chip. The input and output impedance matching over the band was designed to keep the input and output Voltage Standing Wave Ratio(VSWR) of less than 2.0 by connecting a feedback circuit between the drain and the gate. Fig.5

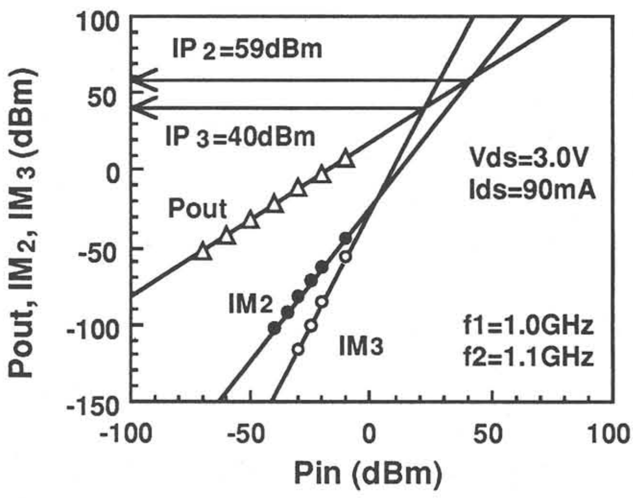

Fig. 5 Comparison of output power, IM_2 and IM_3 against input power.

shows the relations of Pout, IM_2 and IM_3 against Pin of the broadband amplifier by using HEMT of 800μm-gatewidth. The device was biased at Vds of 3V and Ids of about 90mA. Excellent low distortion properties of IP_2 of 59.4dBm and IP_3 of 40dBm at two-tone frequency of 1GHz and 1.1GHz were obtained. The second-order distortion was taken by 2:1 slope and the third-order distortion was taken by 3:1 slope at low input level. These good intermodulation-distortion properties

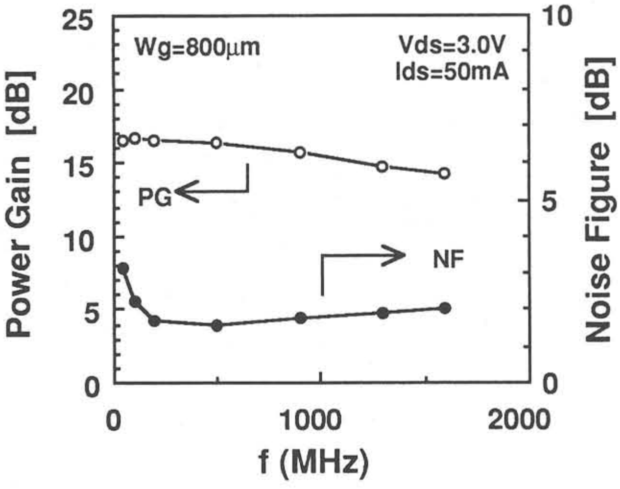

Fig. 6 Noise figure and power gain of the broadband amplifier.

indicate the effectiveness of flat-gm characteristics. A good lineality figure of merit (IP_3/Pdc) of 37.0 was obtained , where Pdc is DC power dissipation[4].

Fig.6 shows power gain and noise figure for the feedback amplifier using a DDQW HEMT of 800μ m -gatewidth. The device was biased at Vds of 3.0V and Ids of about 50mA. The IC has a bandwidth of 4.2GHz with a power gain of 16dB at 1GHz. The noise figure remains less than 2.0dB and the power gain is over 14dB throughout a wide band from 100MHz to 1.6GHz. These results demonstrate the great potential of pseudomorphic AlGaAs/GaAs/InGaAs DDQW HEMTs for low-distortion and low-noise amplifier applications.

4. Summary

AlGaAs/GaAs/InGaAs Double-Doped Quantum-Well HEMTs were grown by solid-source MBE. The fabricated DDQW HEMTs exhibited flat-transconductance characteristics for DC measurement. Moreover, the 800 μm -gatewidth broadband amplifier showed low distortion properties of IP_2 of 59.4dBm and IP_3 of 40dBm at 1GHz, and low-noise properties of less than 2.0dB throughout a wide band of 100MHz to 1.6GHz. This device will be quite suitable for the multi-channel communication systems, and is expected a wide application of high frequency communication apparatus for the next generation such as broadband ISDN or mobile communication systems.

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