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A 44 GHz HEMT AMPLIFIER*

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ABSTRACT

A 44-GHz amplifier using 0.25-μm gate length and double-heterojunction structure HEMT devices is described. Higher gain and power performance have been obtained from the amplifier using this device at millimeter-wave frequencies. A spot gain of 9.4 dB and a 1-dB gain compression point of +7.5 dBm has been achieved at 43.5 GHz.

1. Introduction

High electron mobility transistors (HEMTs) have recently achieved superior lower noise figures both in microwave and millimeter-wave frequency ranges [1-3], but have not yet shown power handling capability. A limitation in using HEMTs in medium-power amplifier applications is that relatively lower power capability of the present single heterojunction transistor has been encountered in comparison with GaAs FETs. It is known that the maximum obtainable saturated drain-source current sets an upper limit on the power output. The primary factor determining the maximum obtainable drain-source current for a single heterojunction transistor is the number of electrons in the two-dimensional electron gas.

To overcome this problem, multiple-channel structure HEMTs have been reported in the frequency range below 30 GHz [4,5]. In this paper, we will describe a 44-GHz HEMT amplifier which has achieved a 9.5-dB gain and a 1-dB gain compression point of +7.5 dBm. This improved performance results from using double heterojunction HEMTs and reducing the source-gate resistance. The HEMT device structure, amplifier development, and performance will also be described.

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2. Device Description

The device using the epitaxial double heterojunction structure was fabricated to improve the current handling capability. A cross section of this double heterojunction structure is shown in Figure 1. This structure has a 300 Å undoped GaAs conductive channel which has electrons supplied from doped AlGaAs layers on both sides of the channel. As a result, approximately twice the sheet electron concentration of the quantum well with one-sided doping is achieved, as indicated by the Hall measurement results presented in Table 1.

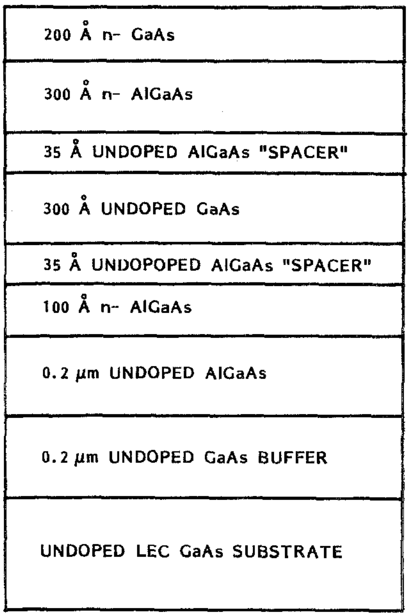

Figure 1. Cross section of double heterojunction HEMT device

Table 1. Hall measurement results for different HEMT structures

RUN NO.	STRUCTURE	μ(300°K) cm^2/V-SEC	n(300°K) ELECTRON/cm^2	μ(77°K) cm^2/V-SEC	n(77°K) ELECTRON/cm^2
2167	SINGLE HETERO-JUNCTION HEMT	7340	1.1 E12	56800	9.2 E11
2409	DOUBLE HETERO-JUNCTION HEMT	5464	2.7 E12	36440	1.6 E12

The HEMT devices were fabricated with 0.25-μm gate length and 80-μm total gate width. The same previously successful basic interdigitated device geometry was also used in this work [1,2]. The ohmic contact was alloyed using nickel, gold-germanium, nickel, and gold contact metals at temperatures above 450°C; the ohmic contact resistance was significantly reduced. Typical I-V characteristics of these HEMT devices are shown in Figure 2. Devices from wafer 2420 have a dc transconductance of 250 ms/mm and an I_{dss} of 28 mA. It has also been observed that the breakdown voltage of these double heterojunction devices is twice that of the single heterojunction devices; this is well suited for the power applications.

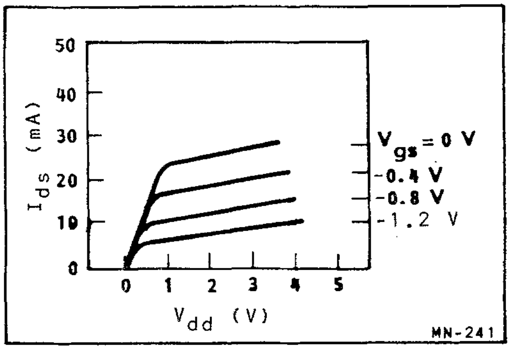

Figure 2. IV characteristics of HEMT wafer #2420

3. Amplifier Development and Performance

A 44-GHz HEMT amplifier has been constructed using MIC technology; microstrip was chosen as the transmission medium. The amplifier hardware consists of the split-block (Figure 3) and provides rectangular waveguides at both the input and output ports. The field converts from the quasi-TEM mode of the microstrip to TE_{10} mode of the rectangular waveguide by using a smooth taper-type transition on the substrate; low insertion loss, low VSWR, and wideband characteristics have been achieved.

The amplifier circuit consists of the above-mentioned waveguide-to-microstrip transition circuit, 50-ohm microstrip line, and bias circuits at both input and output ports. The HEMT device operates in the common source configuration, and

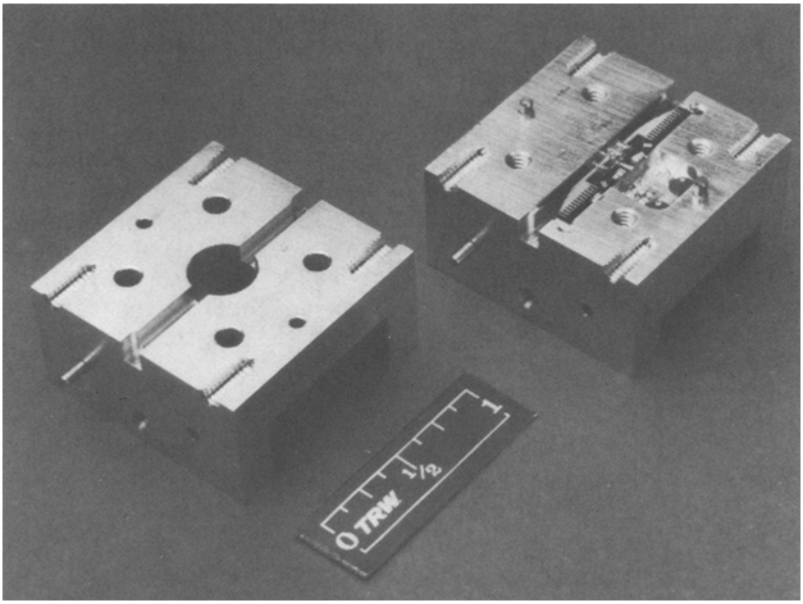

Figure 3. Photo of 44 GHz HEMT amplifier circuit

the RF input and output ports are extracted from the gate and drain of the HEMT, respectively. Bias is fed through the lowpass filter circuit etched on the substrate. Furthermore, the combination of chip resistor and capacitor is employed to provide low frequency stability. A 0.010-inch thick quartz substrate is used; the HEMT device is mounted on a machined ridge located between the ends of two microstrip sections, so the wire bonding effect on the device can be reduced. Tuning patterns and matching circuits on the substrate are obtained experimentally, permitting rapid amplifier development. HEMT amplifiers with the double heterojunction structure devices have been developed. The bias condition and gain performance of a typical HEMT amplifier are shown in Figure 4. When the amplifier was biased as V_{dd} = 4 V, V_{gg} = -0.4 V, and I_{ds} = 21.5 mA, a gain of 9.5 dB and its 1-dB gain compression point of +7.5 dBm have been achieved at 43.5 GHz. Table 2 also lists RF performance results of the HEMT with different structures.

4. Conclusions

The current handling capability of the HEMT device with the single heterojunction structure has been increased by

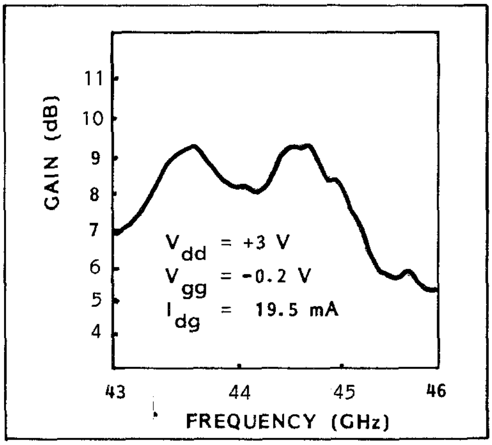

Figure 4. Gain performance of double-heterojunction HEMT amplifier

Table 2. Measured RF performance of HEMT with different structures

WAFER NO.	GAIN (dB)	P (1 dB GAIN COMPRESSION) (dBm)	η (EFFICIENCY) (%)	FREQUENCY (GHz)	STRUCTURE
2241-4	5.6	2.5	4.1	44.5	SINGLE-HETERO-JUNCTION HEMT
2420-2	9.5	7.5	5.5	43.5	DOUBLE HETERO-JUNCTION HEMT

using the double heterojunction structure. In addition, the source-gate resistance of the HEMT has been significantly reduced by alloying gate metallization at temperatures higher than 450°C. Higher gain and power have been obtained with the HEMT amplifier using this double heterojunction structure. The power capability of HEMTs can be further improved by increasing the gate periphery.

References

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