Extended Abstracts of the 1997 International Conference on Solid State Devices and Materials, Hamamatsu, 1997, pp. 430–431 **D-10-5**

High-Performance HEMT with an Offset-Gate Structure for Millimeter-Wave MMICs

H. Ohta, T. Tanimoto[1], I. Ohbu[1], K. Higuchi[1], S. Takatani[1], N. Kurita[1], K. Kamozaki[1] and H. Kondoh[1]

Hitachi ULSI Engineering, Corp., Kodaira, Tokyo 187, Japan
Tel: 0423-23-1111, Fax: 0423-27-7752
[1]Central Research Laboratory, Hitachi Ltd., Kokubunji, Tokyo 185, Japan
Tel: 0423-23-1111, Fax: 0423-27-7752

1. Introduction

There is a growing need for HEMT-based millimeter-wave MMICs in high-speed LAN and automotive crash-avoidance systems[1][2]. Production of commercial MMICs for such systems requires the development of a process technology for practical production of HEMTs with high performance and high reliability. We have fabricated a production-oriented pseudomorphic HEMT by using a newly developed offset gate process. The performance of the HEMT is better than that of a symmetrical gate device, and a 77-Ghz power MMIC using this HEMT has both high performance and high reliability.

2. HEMT fabrication

As shown in Fig. 1, the HEMT has a conduction channel consisting of a delta-doped double-heterostructure InGaAs pseudomorphic HEMT structure. The n^+-GaAs cap layer in the gate-to-drain region is removed to reduce the parasitic drain-to-gate capacitance (C_{gd}) and the drain conductance (g_d). In the gate contact region, both the n^+-GaAs layer and the n-GaAs cover layer are removed.

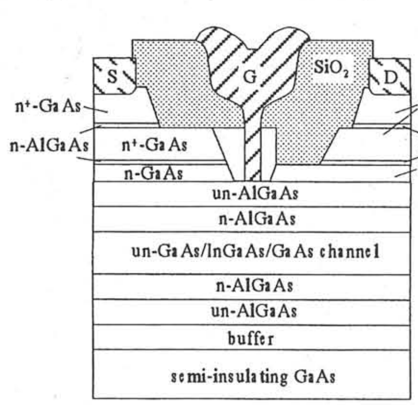

Fig. 1 Schematic cross section of InGaAs pseudomorphic HEMT with offset gate structure.

The n^+-GaAs cap layer is selectively removed by reactive ion etching[3] using a thin AlGaAs stopper layer. The n-GaAs cover layer was also selectively etched using a wet etchant based on citric acid. The high uniformity of these selective etching techniques is advantageous for production. The void structure near the gate contact is expected to prevent device degradation and instability associated with the passivation layer and to reduce the parasitic gate capacitance.

3. HEMT characteristics

A 0.15-μm device with a threshold voltage of -1 V and a gate width of 100 μm showed a saturation current of 50 mA at V_{gs}=0.5 V and a maximum transconductance (g_m) of 55 mS, as determined from the DC characteristics measured at V_{ds}=3 V.

The RF characteristics were measured from 0.1 to 40 GHz and compared with those for a device having a symmetrical gate structure. The extracted equivalent circuit values are shown in Table 1. The drain-to-gate capacitance (C_{gd}) of the symmetrical device was 12.0 fF, whereas for the offset-gate device it was 9.8 fF. The drain conductance (g_d) of 2.86 mS for the symmetrical device was reduced to 1.96 mS for the offset-gate device.

Table 1. Equivalent circuit values of offset-gate HEMT and symmetrical HEMT.

	offset gate	symmetrical
R_s (Ω)	4.8	4.9
R_d (Ω)	10.9	8.8
C_{gs} (fF)	102	102
C_{gd} (fF)	9.8	12.0
g_m (mS)	60	59
g_d (mS)	1.96	2.86

The simulated frequency characteristics of the HEMT power gain are shown in Fig. 2. The offset-gate device has a higher maximum available gain (9 dB at 77 GHz). The maximum frequency of the oscillation (f_{max}) was 170 GHz. Both values are significantly better than those of the symmetrical gate device.

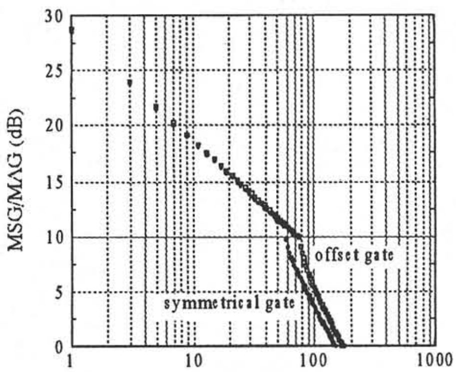

Fig. 2 Simulated frequency characteristics of HEMT power gain.

4. MMIC performance

We fabricated millimeter-wave circuits using 0.15-μ m offset-gate HEMTs. As shown in Fig. 3, a 77 GHz three-stage power amplifier had a small-signal gain of 16.5 dB. We also performed preliminary life testing on the amplifier. As shown in fig. 4, the power gain was stable over 160 hrs of testing, suggesting a room-temperature life of longer than 30 years if the activation energy is assumed to be 1.5 eV, and 12 years if it is assumed to be 1.0 eV.

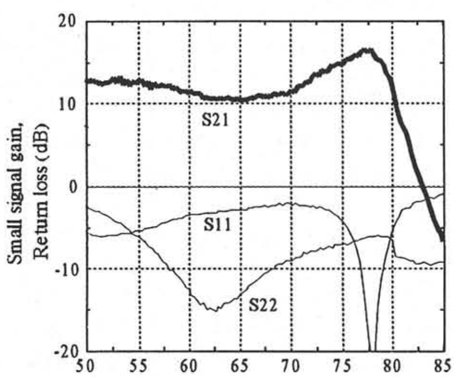

Fig. 3 S-parameters vs frequency characteristics of 77-GHz three-stage power amplifier.

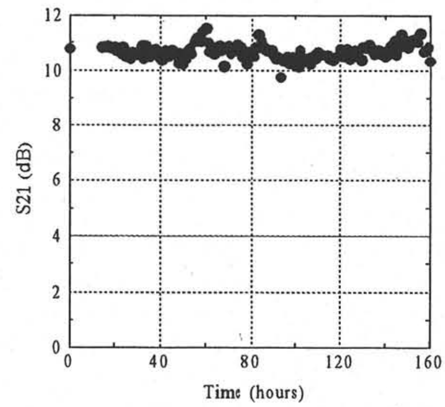

Fig. 4 Variation in power gain at 77 GHz. The device was biased at Vds=3.5 V and Vgs=-0.2 V at 175℃.

5. Conclusion

We have developed an offset-gate process technology for millimeter-wave HEMT MMICs. Our test device showed a markedly high maximum available gain of 9 dB at 77 GHz. A 77 GHz three-stage power amplifier using offset-gate HEMTs was shown to have high performance and stable operation. Our offset-gate HEMT process technology is thus suitable for millimeter-wave MMIC production.

Acknowledgments

We thank Tohru Nakamura, Yoshinori Imamura and Makoto Kudo of the Hitachi Central Research Laboratory for their useful suggestions.

References

1) M. Funabashi, K. Hosoya, K. Ohata, K. Onda, N. Iwata and M. Kuzuhara: IEEE GaAs IC Symposium, pp L 379-L 382 (1993).

2) K. Nakahara, Y. Itoh, Y. Horiie, T. Sakura, T. Katoh, N. Yoshida and T. Takagi: Asia Pacific Microwave Conference, pp L 295-L 298 (1994).

3) T. Tanimoto, M. Kudo, M. Mori and H. Kodera: Jpn. J. Appl. Phys., Vol. 33, pp. L 260-L 262 (1994).