# Results on a HEIFET Including The Gunn Effect

**E. Kolmhofer, K. Luebke, H. Thim**
**Microelectronics Institute, University of Linz, Austria**

A modified version of our 'Hot Electron Injection Field Effect Transistor', utilizing the Gunn effect to enhance microwave performance, is presented. The necessary changes to the device structure and measurement results are given.

## 1. Introduction

The purpose of the work reported is to present the recent modifications which we applied to our **H**ot **E**lectron **I**njection **F**ield **E**ffect **T**ransistor (HEIFET). In our modified structure the ohmic source and drain contacts of a MESFET are both replaced by a combination of an ohmic contact and a Schottky contact. In addition we tried to enhance the function of our device by utilization of the Gunn effect.

## 2. Layout Modifications

In our opinion in the HEIFET structure reported in [1] the most critical geometrical parameter is the separation between the MESFET gate and the overlapping gate. Due to improvements in our electron beam lithography system we have been able to reduce the length of the MESFET gate to values around 0.4 µm and the separation to values around 0.3 µm. Unfortunately these and other modifications indicated in [1] failed to raise our transistor's frequency limits significantly. Particularly the transit frequency of the unilateral power gain $f_{max}$ (maximum frequency of oscillation) remained below our expectations. In order to improve the microwave behavior of our devices we decided to utilize the Gunn effect.

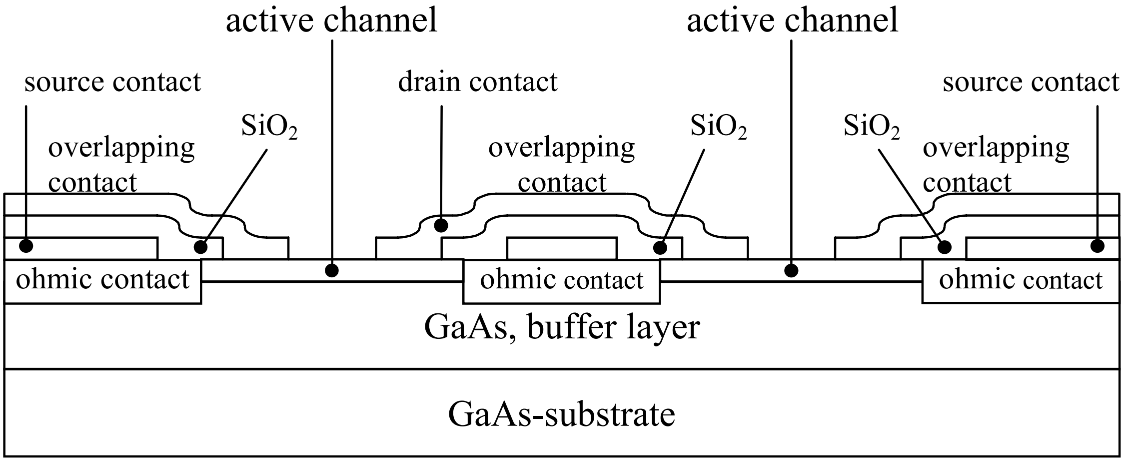

Fig. 1: Cross sectional view of the modified HEIFET.

In GaAs the Gunn effect weakens with increasing doping density and almost completely disappears at the value of $N_D = 2 \cdot 10^{17}$ cm$^{-3}$ which we used. Therefore a reduction to $N_D = 4 \cdot 10^{16}$ cm$^{-3}$ was necessary. The reduction of drain saturation current coming along with a lower $N_D$ has been remedied by increasing the channel's width and thickness. The second significant modification was replacing the MESFET gate with a gate overlapping the ohmic drain contact. Figure 1 shows a cross sectional view of the modified HEIFET structure.

## 3. Measurement Circuit

The microwave probing of the devices, manufactured in the cleanroom of the Microelectronics Institute, has been carried out on a Cascade Microtech waverprober using a HP 8510C vector network analyzer. Since our waverprober is equipped with ground-signal-ground coplanar probes the transistors have been built symmetrically resulting in the layout shown in Fig. 2.

Fig. 2: Symmetric layout of the measurement circuit.

The symmetric layout of the transistor and the circuit help in avoiding measurement errors which arise from unsymmetrical modes in the GSG waverprobing setup. Furthermore the use of two channel regions helps in achieving the necessary width of the device. For biasing the ohmic and the Schottky drain contact the bias-tees built into the HP 8510C can be used.

## 4. Results

Using the setup described above the modified HEIFETs have been measured in a frequency range from 45 MHz to 50 GHz. Figure 3 shows typical deembedded S-parameters of one of our devices while Fig. 4 shows the unilateral power gain $U$ calculated from these S-parameters. From Fig. 3 and Fig. 4 it is obvious that the device operates up to a frequency of 45 GHz. The unilateral power gain determines the maximum frequency of oscillation reachable with a device which is therefrom found to be 45 GHz.

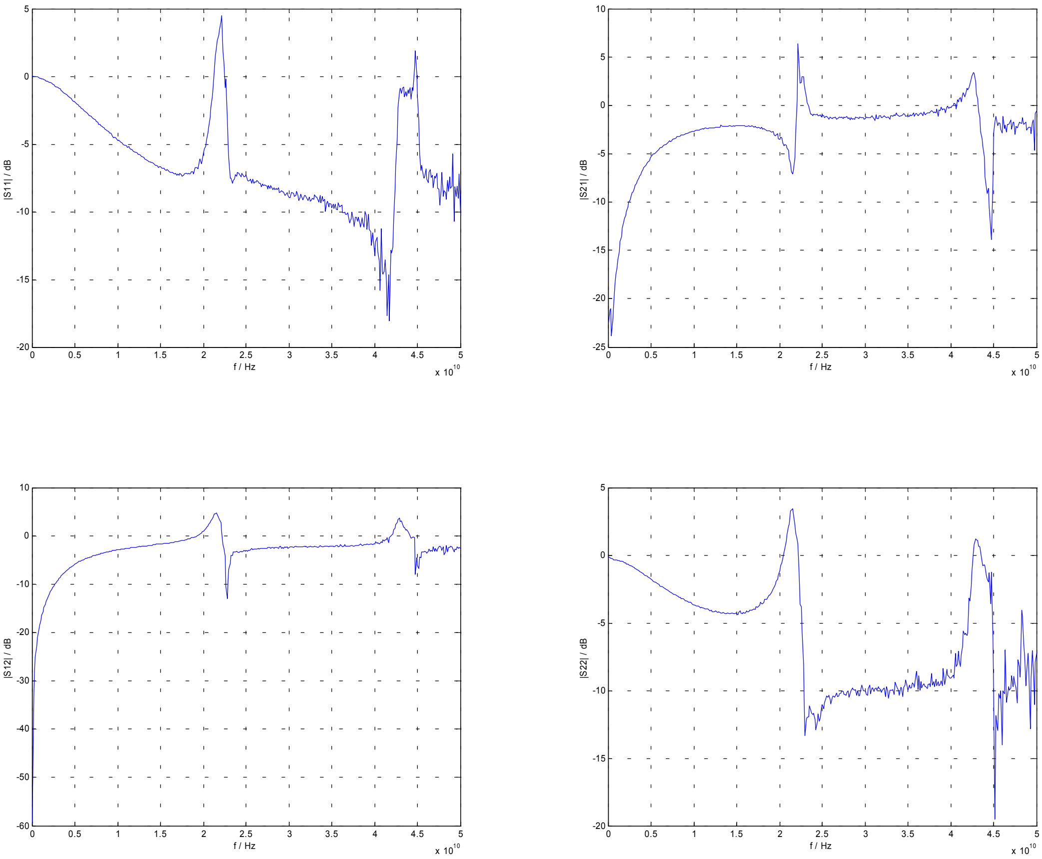

Fig. 3: Deembedded S-parameters of a modified HEIFET.

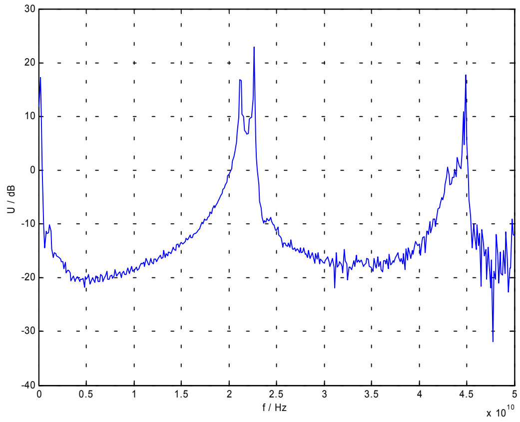

Fig. 4: Deembedded unilateral power gain of a modified HEIFET.

## 5. Conclusion

The modifications applied to the HEIFET helped to raise the upper limiting frequency of the HEIFET to at least 45 GHz which can largely be attributed to the utilization of the Gunn effect. Operation of our actual HEIFETs could be possible at even higher frequencies which currently lie beyond our measurement capabilities. Further experimental work will include the design of HEIFET based oscillator circuits.

## Acknowledgements

The authors would like to thank M. Hinterreiter and J. Katzenmayer for fabricating the devices. This work is supported by the Austrian Science Foundation (FWF) under contract No. P12702 TEC.

## References

[1] E. Kolmhofer, K. Luebke, H. Thim, “Hot Electron Injection Field Effect Transistor”, *Annual Report 2000*, Society for Microelectronics.