WeP1-16

Numerical Simulation of Microwave MESFETs in 4H-SiC Fabricated Using Epitaxial Layers on Semi-Insulating Substrates

T. Ayalew*, S. Wagner*, T. Grasser*, and S. Selberherr°

* Christian Doppler Laboratory for TCAD in Microelectronics at the Institute for Microelectronics
° Institute for Microelectronics, TU Vienna, Gußhausstraße 27–29, A-1040 Wien, Austria
Phone: +43-1-58801/36025, Fax: +43-1-58801/36099, Email: Ayalew@iue.tuwien.ac.at

We present results of the numerical simulation of advanced SiC microwave devices. The high breakdown voltage and high thermal conductivity coupled with high carrier saturation velocity allow SiC microwave devices to handle much higher power densities than their silicon or GaAs RF counterparts. A variety of microwave devices with impressive DC and RF performance including MESFETs (MEtal Semiconductor Field-Effect Transistors), SITs (Static-Induction Transistors), and HBTs (Heterojunction Bipolar Transistors) have been demonstrated and these devices are developed for microwave power amplifier and oscillator applications [1]. The numerical investigation of a MESFET in 4H-SiC fabricated using epitaxial layers on semi-insulating substrate shown in Fig. 1 was performed. The key parameters that alter the overall device performance (Table 1) including the extrinsic and intrinsic elements have been optimized using the general-purpose device simulator MINIMOS-NT [2]. For the calibration of the simulator the specifications obtained from Cree's CRF-24010 4H-SiC MESFET [3] are used.

The simulated and measured DC IV characteristics are compared in Fig. 2. Excellent agreement between the simulated and measured data were obtained. This MESFET produces a maximum channel current of about 250 mA/mm. The ability of the gate bias to turn the device off and on is good, as indicated by the channel current with zero and high reverse gate bias applied. The ability of the device to modulate the current is given by the device transconductance which for this device is about g_m=160 mS/mm. The zero gate voltage drain current at V_{DS} = 10 V is 0.42 A/mm. This device has a drain source breakdown voltage of 110 V with a leakage current of 1 μA/mm as depicted in Fig. 3. Since a good agreement is obtained between both the measured and simulated DC performance, the simulator can be used for a variety of purposes. Small-signal AC simulation is conducted for the frequency range from 100 MHz to 40 GHz to determine the desired small signal RF characteristics of 4H-SiC MESFET. The measured and simulated S-parameters for this device are depicted in Fig. 4. Very good agreement between the simulated and measured data was obtained. It is important to note that the RF results presented here were obtained at a high drain-to-source bias voltage of 40 V and gain-to-source voltage of -9 V.

Other important performance figures of merit for RF devices are extracted from the S-parameter values: the cut-off frequency f_t, the maximum frequency f_{max}, the unilateral power gain (Masson's gain, U), the maximum available gain (MAG), and the maximum stable gain (MSG). The f_t (unity current gain frequency) can be calculated by extrapolation of the short circuit current gain parameter H_{21}. The value of f_{max} can be determined from the MAG and MSG. The small-signal current and power gain shown in Fig. 5 yields an f_t = 5.62 GHz and f_{max} = 37.18 GHz at 0 dB H_{21} and MAG/MSG, respectively. This device produced 15 dB at 1 GHz. These results clearly demonstrate the advantages of 4H-SiC for high-power microwave application where its high-thermal conductivity, high-voltage, and high-power density capability are very attractive.

REFERENCES

[1] A. P. Zhang, L. Rowland, E. B. Kaminsky, J. W. Kretchmer, R. A. Beaupre, J. L. Garrett, J. B. Tucker, B. J. Edward, J. Foppes, and A. F. Allen, "Microwave Power SiC MESFETs and GaN HEMTs," in *Proceedings of the IEEE Lester Eastman Conference on High Performance Devices*, pp. 181–185, 2002.

[2] Institute for Microelectronics, TU Vienna, Austria, *Minimos-NT, Device and Circuit Simulator, User's Guide*, 2002. http://www.iue.tuwien.ac.at/mmnt/.

[3] Cree, "Cree's Silicon Carbide RF Products." http://www.cree.com/Products/rf_sicproducts.asp.

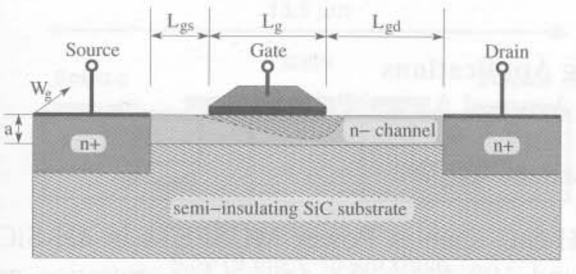

Figure 1: Cross section of 4H-SiC MESFET.

parameter	value
gate length L_g	$0.5\,\mu$m
gate width W_g	1 mm
source-drain spacing	$2\,\mu$m
channel doping N_d	$5\times10^{17}\ \mathrm{cm}^{-3}$
channel thickness a	$0.15\,\mu$m

Table 1: Optimized device parameters.

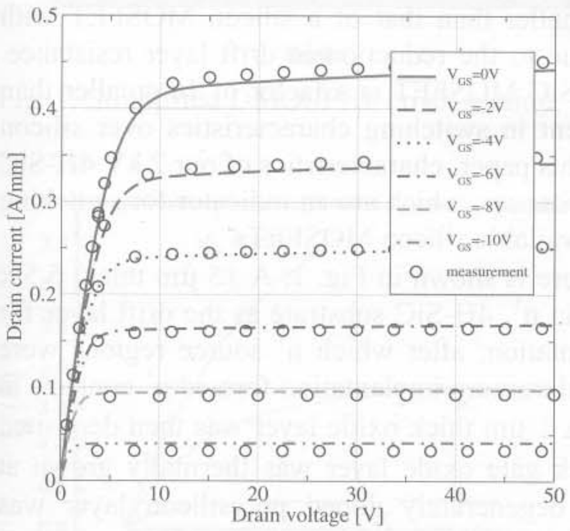

Figure 2: Comparison of measured and simulated DC IV characteristics of a 4H-SiC MESFET.

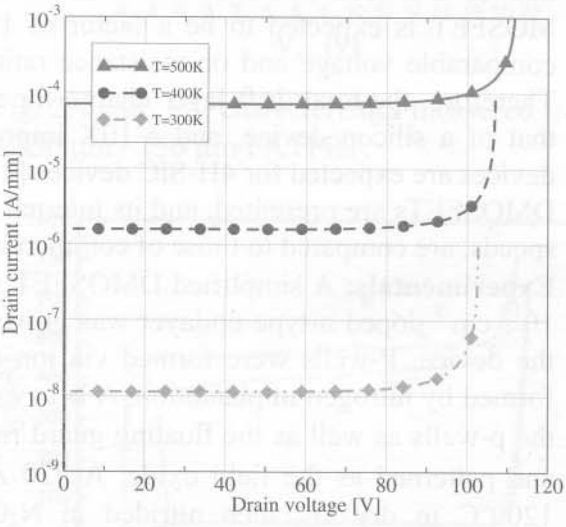

Figure 3: Reverse bias characteristics of a 4H-SiC MESFET.

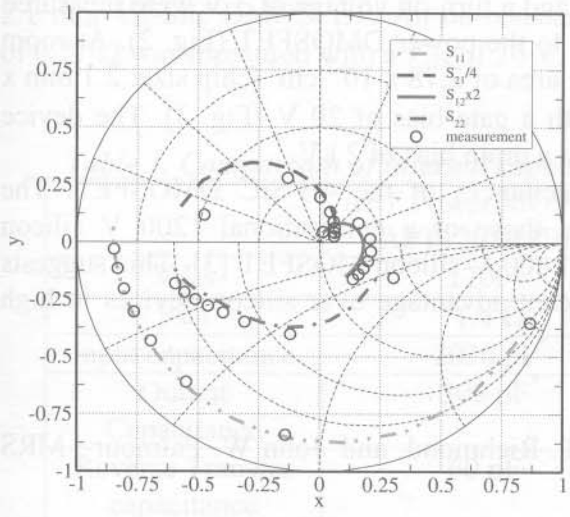

Figure 4: Comparison of measured and simulated S-parameters in a 4H-SiC MESFET.

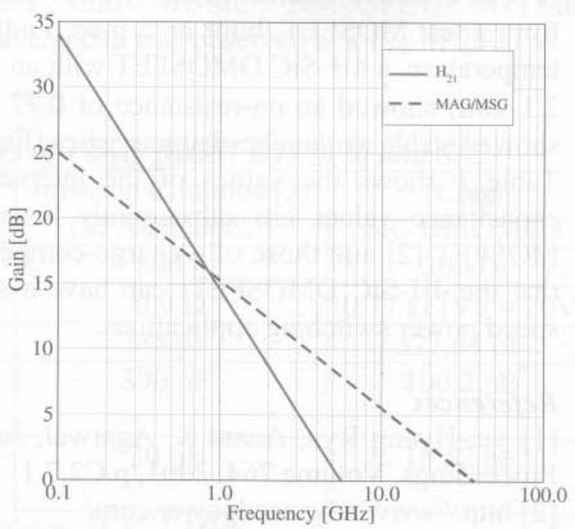

Figure 5: Small-signal current and power gain for an optimized 4H-SiC MESFET.