Investigation of hysteresis effects in device characteristics of AlGaN/GaN-HFETs caused by polarization charges

R. STENZEL[1], W. Klix[2], A. Vescan[3], R. Dietrich[3], A. Wieszt[3] and H. Leier[3]

[1]*University of Applied Sciences Dresden, Friedrich-List-Platz 1, D-01069 Dresden, Germany*
[2]*University of Technology Dresden, Mommsenstr. 13, D-01062 Dresden, Germany*
[3]*DaimlerChrysler AG, Research and Technology, Wilhelm-Runge-Str. 11, D-89081 Ulm, Germany*

Abstract

Internal strain in the commonly used wurtzite phase of GaN may lead to the generation of large piezoelectric polarization fields and in addition to spontaneous polarization (at zero strain) which causes additional sheet charges at the heterojunction interfaces of the structures. Numerical simulations have been carried out to study the influence of these effects on carrier distributions and on static and dynamic device characteristics of AlGaN/GaN-HFETs. During these simulations differences in output characteristics could be observed if the drain-source-voltage was increased and then decreased. This hysteresis behaviour was confirmed by experimental results.

For the simulation we used our 2D/3D-program SIMBA [1] which consists of a modified drift-diffusion algorithm. Optional it can be extended by the solution of the effective mass Schrodinger equation to calculate the exact electron density within the two-dimensional electron gas (2DEG) channel. For the inclusion of polarization charges additional terms in the Poisson equation are inserted. Fig. 1 shows the calculated $Al_{0.25}GaN/GaN$-HFET-structure. The effects of spontaneous and piezoelectric polarization are included by a positive interlayer charge σ_i at the heterojunction interface, a negative surface charge σ_s and a negative interlayer charge σ_b at the GaN/AlN heterojunction (The AlN layer is inserted between SiC substrate and GaN buffer and was neglected at the simulation). The total sheet charge density for $Al_{0.25}GaN/GaN$ is in the range of $\sigma_i = 1.6 \cdot 10^{13}$ cm^{-2} [2]. We assumed $\sigma_s = -6 \cdot 10^{12}$ cm^{-2} and $\sigma_b = -2.5 \cdot 10^{12}$ cm^{-2} by comparison with experimental results. Fig. 2 shows the output characteristics at $V_{gs} = 0$, if V_{ds} is increased from 0 to 20 V and then decreased to 0. Two different characteristics accrue. The reason for this behaviour is mainly the polarization charge at the device bottom, if the potential at the backside of the device is not fixed. In this case at the beginning of the simulation at small voltages V_{ds} the backside potential is near zero and so at the same level as source potential. At increasing voltages V_{ds} the space charge region resulting from the bottom charge enlarges and the backside potential floats to negative values (it loses the connection to the source potential). Thus a different characteristic occurs, the drain current becomes smaller. The paper will illustrate these effects by the presentation of potential and electron density distributions for the two different states.

[1] R. Stenzel, C. Pigorsch, W. Klix, A. Vescan, H. Leier, *Int. Symp. Compound Semiconductors, Berlin 1999*
[2] H. Morkoc, R. Cingolani, B. Gil, *Solid-State Electronics, 43(1999), pp.1909-1927*

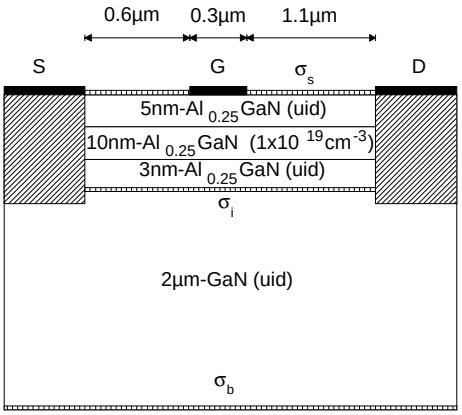

Fig. 1 Device structure

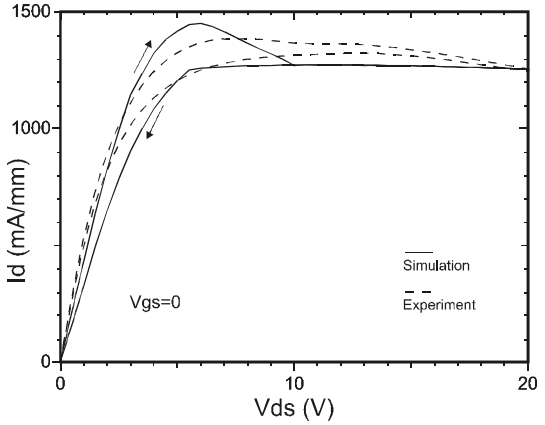

Fig. 2 Output characteristics