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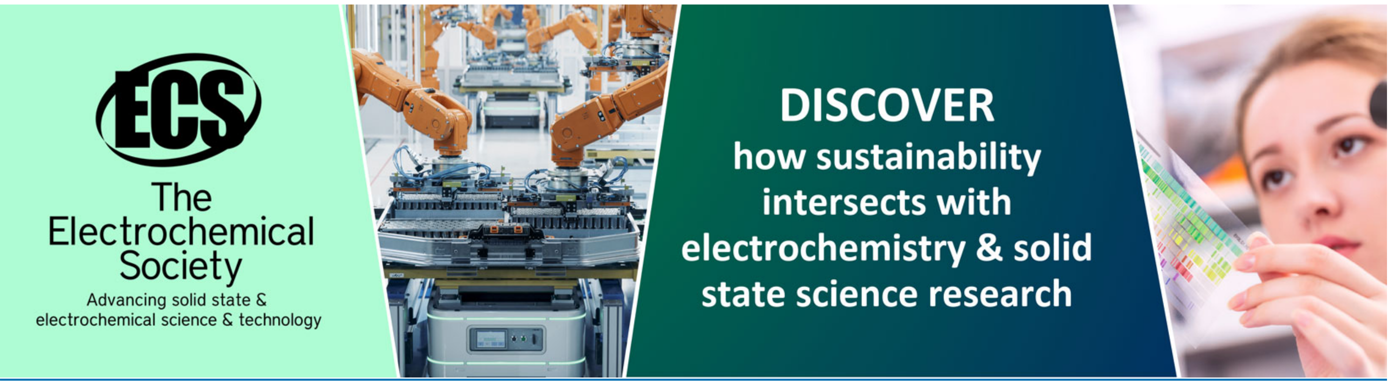

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Evaluation of the influence mode on the CVC GaN HEMT using numerical modeling

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Abstract. Done numerically simulated the effects of certain modes of operation on the CVC of field microwave transistors on the basis of heterostructures AlGaN / GaN (HEMT). The results of these studies suggest the possibility of quite efficient use of numerical simulation for the development of HEMT microwave transistors allowing for the real instrument designs.

1. Introduction
The use of the mathematical modeling methods, based on the multidimensional numerical models of calculation of the carrier transport, thermal processes and dynamical characteristics helps to add, check and explain existing experimental data. Also behavior of the device structures with changing parameters can be predicted that is difficult to reproduce experimentally [1-3]. In this work we present the results of numerical modeling of influence of some operating parameters and external impacts on the current-voltage characteristics (CVC) of field effect transistors – high electron mobility transistor (HEMT), based on the AlGaN/GaN heterostructures.

2. Results and discussion
Prediction of field effect transistor output characteristics requires the model which includes the statistics of carrier distribution in the heterostructure layers, peculiarities of carrier transport and electron mobility in the HEMT channel to account the heating up of the carriers and adequate description of current processes under external impacts. A typical AlGaN/GaN HEMT was selected as the object of our modeling. It consists of a 4H semi-insulating silicon carbide (SiC) substrate, a buffer layer of unintentionally doped (UID) 3 µm-thick GaN, 20 nm – thick AlGaN barrier layer. The chematic cross section of the modeled AlGaN/GaN HEMT is shown in Figure 1.

We have optimized the mathematical models used to analyze the characteristics of our heterostructures in accordance with recommendations given in work [4]. A two-dimensional hydrodynamic mathematical model is used in many industrial simulation systems [5], which, combined with the original models of the electrons behavior in material media, gives good results [2]. Similar approaches are described in other works [6-8]. When selecting a model of electron transport, we take into account the balance between the speed of calculations and the required accuracy. The calculation of the drift-diffusion model does not meet the demands of practice in the calculation of sub-micron transistors [9]. We believe that combining of the Monte Carlo method with the well-

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established and calibrated hydrodynamic model is the best choice in many cases. We have solved the system of four differential equations in partial derivatives: electric field Poisson's equation, current continuity equation, the heat flux (the lattice heat flow equation) and energy balance for the electrons, which are solved self-consistently. This system of equations is supplemented by specific equations for material media (the mobility of the carriers, the electron density, thermal conductivity, etc).

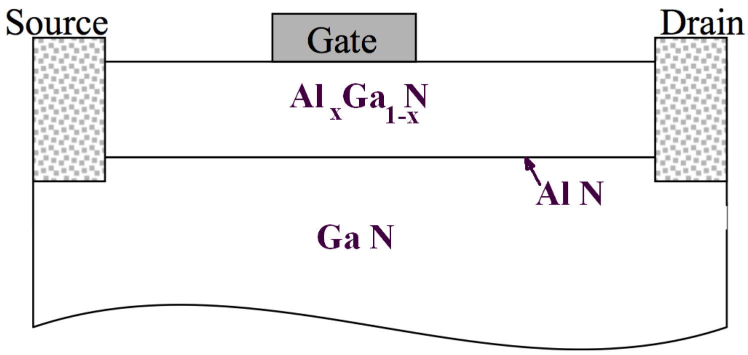

Figure 1. Schematic cross section of the modeled AlGaN/GaN HEMT.

First, we have adapted the numerical models to the features of transistor device design and its technology [2, 3]. Next, the calculation of the static current-voltage and capacitance-voltage characteristics of the HEMT has been done. Figure 2 shows the experimental and calculated static current-voltage characteristics of the modeled AlGaN/GaN HEMT. The very good agreement of modelling results and experimental data were achieved.

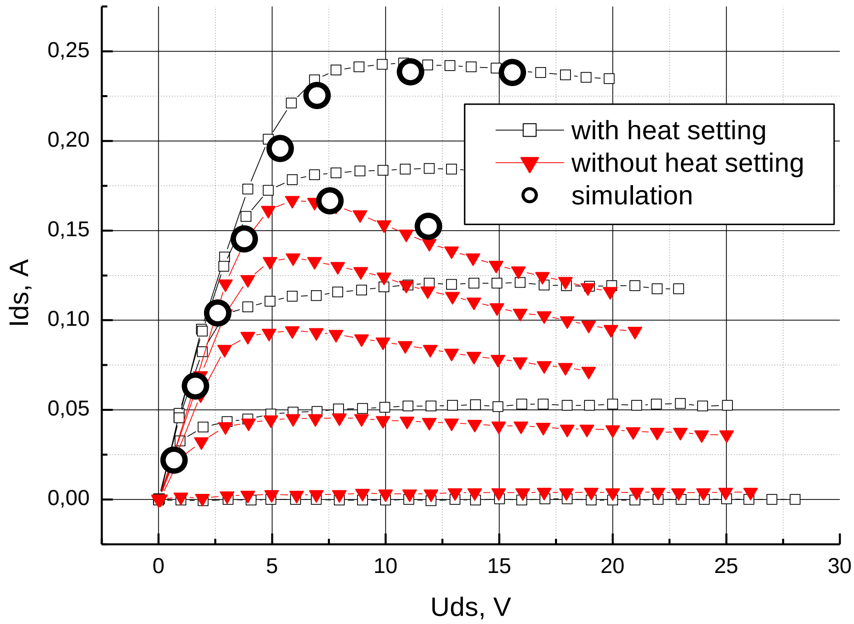

Figure 2. Experimental and calculated in the self-heating of the transistor current-voltage characteristics with and without heat setting.

Next the impact of the temperature on the current-voltage characteristics of AlGaN/GaN HEMT was studied. As described in [10] the heating of the device may results in degradation of the ohmic contacts and in worsening of the CVC of the semiconductor device. Numerical modeling of ohmic contacts degradation under heating was carried out. The dependence of contact resistance (R_C) on the temperature (T) and the time (t) can be written as follows:

$$R_C = R_{C0} + \gamma \cdot \exp\left(\frac{-E_a}{2kT}\right) \cdot \sqrt{t}\ ,$$

where R_{C0} is the contact resistance at the initial time. For contact area S_C = 25 mm^2 and specific contact resistance of 10^{-6} Ohm cm^2 [10], R_{S0} is 4 Ohms. Using the equation and these parameters we calculated CVC of AlGaN/GaN HEMT before and after heating. The effect of the temperature was modeled in five cycles of varying time duration at T = 300 °C. Parameters of the simulated temperature cycles are shown in Table 1.

Table 1. The duration of the temperature effect on transistor.

№ of cycle	time tc, hour	total time of thermal impact tΣ, hour
1	1	1
2	2	3
3	5	8
4	10	18
5	9	27

The simulation results of the temperature impact on the current-voltage characteristics of AlGaN/GaN HEMT with a gate width of 100 μm are shown in Figure 3.

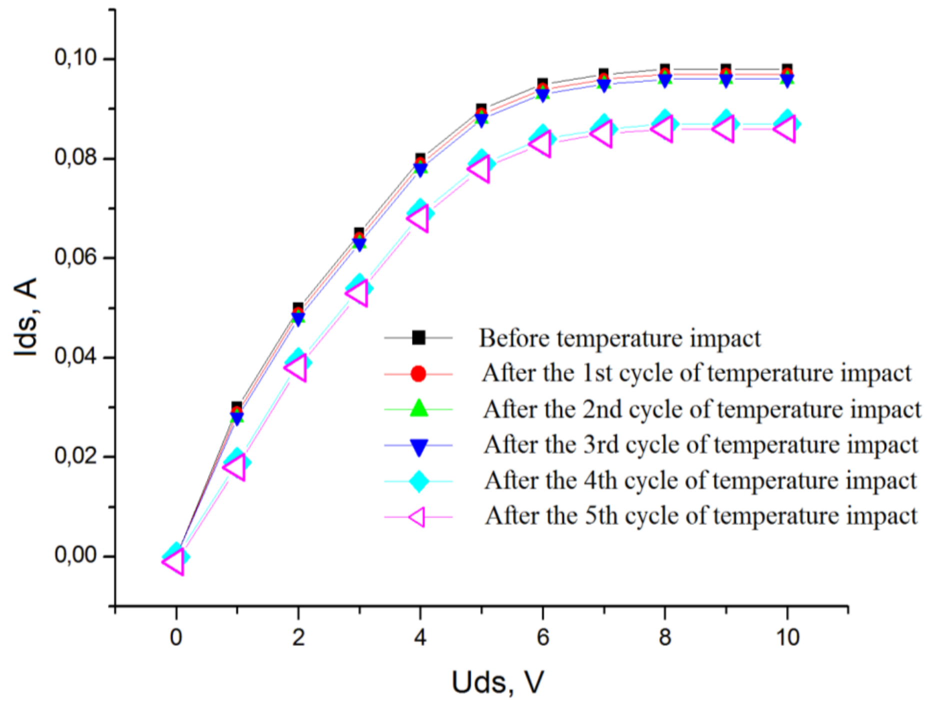

Figure 3. Current-voltage characteristics of AlGaN/GaN HEMT during 5 cycles of heating.

We observe the noticeable change in the CVC behavior after the 4th cycle of thermal impact with duration of 10 hours with and 18 hours of the total heating time. At the subsequent cycle of thermal exposure significant changes of CVC form does not occur compared to previous form of the CVC, measured after the 4th cycle of temperature effects.

3. Conclusion

To conclude, the numerical model of the AlGaN/GaN HEMT is developed. The results of numerical modeling of AlGaN/GaN HEMT current-voltage characteristics and the heating effect are presented. In is shown that the noticeable changes in the shape of CVC begin to appear only after the 4th cycle of thermal impact with duration of 10 hours (total time of thermal impact is 18 hours).

Acknowledgments

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