FIZIKA Volume 21, Supplement 1, 1989.
Proceedings of the XI Yugoslav SYMPOSIUM OF THE PHYSICS OF CONDENSED MATTER.
M. Davidović and M. Lj. Napijalo Editors, Donji Milanovac, October 3–7, 1988.

# THE TWO-DIMENSIONAL ANALYSIS OF THE DISTRIBUTION OF CHARGED CARRIERS IN AN Al-GaAs $n^+$-n-$n^-$ HETEROGENEOUS STRUCTURE UNDER THE INFLUENCE OF THE EXTERNAL ELECTRIC FIELD

R. Ramović*, A. Guljaš**, D. Indin*, Z. Ristovski*

* - Faculty of Electrical Engineering, Beograd

** - Factory of equipment and plants, Kneževo

*ABSTRACT - Starting from the basic equations for describing the phenomena in the electron transport processes in solid states /1/, /2/, the two-dimensional mathematical-physical model was proposed and used for numerical calculations of the distribution of charged carriers. A heterogeneous structure on the basis of Al-GaAs, where the layer GaAs is unevenly doped from intrinsic to very large concentration of impurities, was studied.*

## 1. INTRODUCTION

Particular structures are becoming increasingly topical due to their applicative characteristic in electronic. One of such structures is the Metal-Semiconductor-Filed-Effect-Transistor's structure, plotted on Fig.1, which is the topic of the analysis of the present paper.

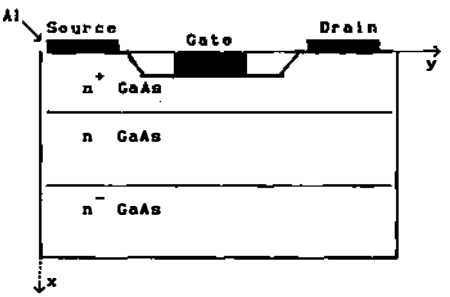


Fig.1. Ga-As MESFET structure

In the analysis of electron transport processes in such structures we start from Maxwell's equations in the most general form, on the basis of which the following system of equations is reached:

$$\operatorname{div} \vec{J}_n - q\frac{\partial n}{\partial t} = qR(\Psi, n, p) \qquad (1)$$

$$\text{div}\ \vec{J}_p + q\frac{\partial p}{\partial t} = -qR(\Psi, n, p) \qquad (2)$$

$$\vec{J}_n = -q\left[\mu_n n\ \text{grad}(\Psi) - D_n\ \text{grad}(n)\right] \qquad (3)$$

$$\vec{J}_p = -q\left[\mu_p p\ \text{grad}(\Psi) + D_p\ \text{grad}(p)\right] \qquad (4)$$

$$\text{div grad}(\Psi) = \frac{q}{\varepsilon}(n-p-c) \qquad (5)$$

Only in some special cases we can arrive at the explicit analytical solution of the quoted system of equations. In the most general case the solution for the carrier concentrations $n$ and $p$, potential $\Psi$ and current densities $J_n$ and $J_p$ is reached by a numerical procedure of solving the system of equations (1)-(5).

## 2. MATHEMATICAL-PHYSICAL MODEL, CALCULATION, RESULTS

For the calculation of the potential distribution, and carrier's concentration in some structure, the system of equations (1)-(5) can be reduced to the following three equations:

$$\text{div grad}(\Psi) - \frac{q}{\varepsilon}(n-p-c) = 0 \qquad (6)$$

$$\text{div}\left[D_n \text{grad}(n) - \mu_n n\ \text{grad}(\Psi)\right] - R(\Psi, n, p) = \frac{\partial n}{\partial t} \qquad (7)$$

$$\text{div}\left[D_p \text{grad}(p) + \mu_p p\ \text{grad}(\Psi)\right] - R(\Psi, n, p) = \frac{\partial p}{\partial t} \qquad (8)$$

By the numerical solution of system (6)-(8) with the definition of necessary boundary conditions for the structure from Fig. 1, and with the adoption of corresponding models for particular parameters such as mobility ($\mu_n, \mu_p$), diffusion coefficient ($D_n, D_p$), recombination-generation speed and the life-times of carriers, we arrived at the carrier's distribution in the structure under consideration in the stationary regime, in the two-dimensional form. The method of finite differences /1/, /2/, /3/ was used in the calculation

Taking that the distribution of the concentration impurities in GaAs is of the Gaussian type, we get the $n$ and $p$ distributions in the structure from Fig. 1, for various values of the voltage between the metal parts. On Fig. 2 the distribution of the electron concentration and on Fig. 3 the distribution of hole concentration for $V_{gs}$=-0.5V, $V_{ds}$=1V is presented.

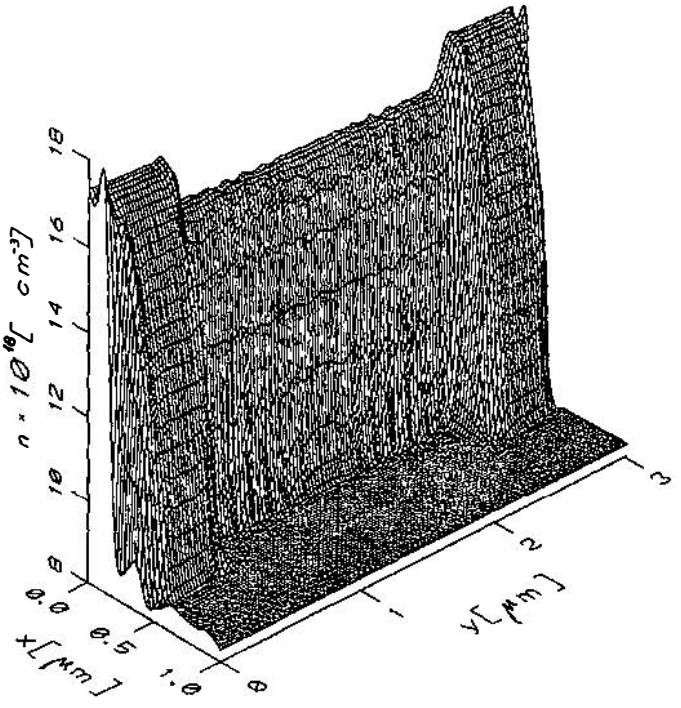


Fig.2 Distribution of electron concentration

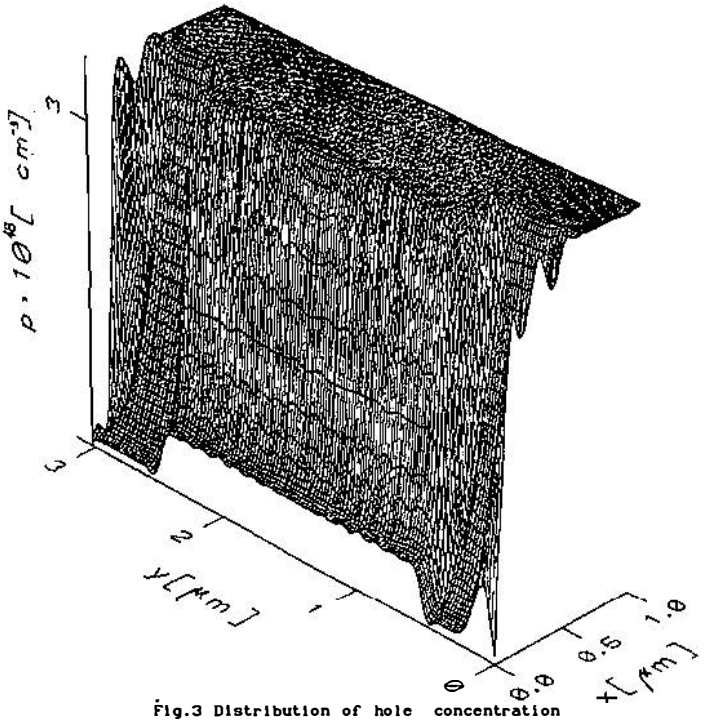


Fig.3 Distribution of hole concentration

The results obtained were compared with the results from literature obtained for similar structures through other numerical approaches (Monte-Carlo simulation /4/,/5/ and /6/). The qualitative agreement can be found, though more accurate comparison is difficult to be achieved, due to various particular technological and geometrical parameters of the structure under consideration in this paper and those in literature. Here the data for GaAs were taken according to Ref. /7/.

## 3. CONCLUSION

The models and the calculation algorithms developed in this paper together with the results obtained provide a possibility to simulate the transient current-voltage characteristics, those considered as well as some similar structures. Having in view the influence of technological and geometrical parameters on the charged carrier's distribution and thereby on the final current voltage characteristics on the basis of this structure, these characteristics can, in this manner, be optimized by choice of parameters.

## REFERENCES


/1/ W. L. Engl, "Process and Device Modeling", North-Holland, New York, 1986.

/2/ S. Selberherr, "Analysis and Simulation of Semiconductor Devices", Springer-Verlag Wien, 1984

/3/ R. Ramović, D. Tjapkin, J. Marinković, "A two-dimensional analysis of carrier's transport in the MOS structures" Fizika, vol. 12, Supplement 1, 1980., pp. 50-54.

/4/ Y. Awano, K. Tomizava, "Monte Carlo Particle Simulation of a GaAs Short-Channel MESFET", Electronics Letters, Vol. 19. N°1, January 1983.

/5/ C. K. Willians, T. H. Glisson, "Two-dimensional Monte Carlo simulation of a Submicron GaAs MESFET with a Nonuniformally doped Channel, SEE, Vol. 28, 1985.

/6/ M. Abusaid, J. Hauser, "Calculation of High Speed Performance for Submicrometer Ion Implanted GaAs MESFET Devices", IEEE Transactions on Electron Devices, Vol. ED-33, N° 7, July 1986. pp. 913-918.

/7/ T. S. Moss, "Handbook on Semiconductors" North-Holland Publishing Company, Amsterdam, 1986.