Two-dimensional Modeling of Depletion Layer of MESFET GaAs

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Abstract- A two-dimensional numerical analysis is presented to investigate the field effect transistor characteristics, the influence of the geometry of the component like distance between the gate and drain, or between gate and source. All simulations revealed the existence of a high electric field region near the gate contact, who create a depopulated zone around the gate, but the preceding studies have neglects the edge effects, which are very significant for the submicron components. Key words: Modeling, MESFET, depopulated zone

I. INTRODUCTION

With current technological progress, the submicron component are then more powerful, but the complexity of their function increases as soon as dimensions are reduced. In the ultra-high frequencies domain, the field-effect transistors constitutes one of the best elements for the realisation of the component with basic functions, such the power component, the frequency conversion or the amplification with weak noise.

The development or the improvement of new dies of components requires means for the modelling, the realisation and the characterisation [1], [2].

It is thus very significant to predetermine the characteristic of the component, physical-modelling finds here one of its principal application.

Taking into account the complexity of the operation of a field-effect transistor to gate submicron, according to the application chosen, the optimisation of the component according to the geometrical and physical parameters is not possible by only experimental approach [2], [8]. It is imperative to understand the phenomena, which exists, the variation of only one technological parameter being able to have various consequences on the characteristics and possibilities of field-effect transistor. Those are not easily analysable without a precise determination of the internal parameters which govern it [3], [4].

Physical simulation finds here two reasons principal:

The exploratory study: Investigation of a new components, requires an estimate of its potentialities before reaching the stage of the realisation, this minimises the production cost [5], [6], [7].

The qualitative study: The designer of the components must know the influence of the technological parameters, so that this one can envisage their influence on the behaviour of the device. In particular when it is about monolithic integrated circuit microwaves [8].

This paper investigates the gate-bias dependence of a field-effect transistor to gate submicron depth of the depopulated zone. The influence of the effect edge on the profile of the depopulated zone and the charge distribution is investigated.

Computer-aided analysis is a useful technology for studying physical phenomena in semiconductor devices. In this work we have made two-dimensional simulation of component with field effect’s considering the effect of edge and the real position (source, gate, and drain), of our structure Figure 1. Since then there have been a number of theoretical papers but lot of used the one dimensional modeling [3], [9].

II. TWO-DIMENSIONAL ANALYTICAL MODEL

Figure 1, shows a normal planar field effect transistor simulated in this study. We use the analytical model determines by [2], this model is based on the function of Green,

\[ G(\frac{x}{x_0}, \frac{y}{y_0}) = -\frac{1}{4\pi} \log \left[ \frac{\sin^2(R^2) + \sinh^2(T)}{\sin^2(R^2) + \sinh^2(T)} \right] \] (1)

With:

\[ R^2 = \frac{1}{2} \left[ \cos^{-1}\left( \frac{x}{b} \frac{1}{z} \right) \pm \cos^{-1}\left( \frac{x_0}{b} \frac{1}{z_0} \right) \right] \] (2)

\[ T = \frac{1}{2} \left[ \cosh^{-1}(z) - \cosh^{-1}(z_0) \right] \] (3)
III. CALCULATION of the POTENTIAL

Here, we give Poisson's equation in all space considering quasi-static mode, the relation between the potential, the charge density and the permeability is:

\[
\nabla \cdot \varepsilon(x, y) \cdot \nabla (V(x, y)) = -\rho(x, y)
\]

with

\[
\rho(x, y) = \begin{cases} 
\rho_{s} & \text{on the metal} \\
\rho_{0} & \text{on ZD} \\
0 & \text{Other}
\end{cases}
\]

and

\[
\varepsilon(x, y) = \begin{cases} 
\varepsilon_{0} & \text{in vacuum} \\
\varepsilon_{s} & \text{in SC}
\end{cases}
\]

Figure 2 shows section of a normal planar field effect transistor divided on two domains. The potential calculates in the positive area is written:

\[
V(x, y) = \frac{1}{\varepsilon_s} \int_{z_0}^{\infty} [\rho(x, y)] G(x/x_0, y/y_0) \, dx_0 \, dy_0 + V_a(x, y)
\]

(10)

\[
V_a(x, y) = \frac{2}{\varepsilon_{0} + \varepsilon_{s}} \int_{m} \rho_{s}(x) G(x/x_0, y/y_0) \, dx_0
\]

(11)

with

\[
R = \frac{\varepsilon_{s} - \varepsilon_{0}}{\varepsilon_{s} + \varepsilon_{0}}
\]

(12)

\[zd = \text{depletion zone} \]

Simulation

Figure 3 shows the simulation program.

- The potential V represents the potential applied \(V_{G}\) plus the potential of barrier \(V_{b}\).
- The calculation of the limit of the depopulated zone is made by combining the equation (3), with the following hypotheses:

\[
V(x, y) = V \text{ on the metal conductor}
\]

\[
V(x, y) = 0 \text{ On the Profile of the depopulated zone.}
\]

One leads to a system of the non-linear equations. The resolution by the method of moments (Figure 3), allows to know in the form discredited the depopulated zone profile. As well as the electric charge distribution.
- We use a vector initial which is determined by the one dimensional approximation of Shockley[3].

VI. RESULTS

The figures (4), (5), (6), (7) shows the variation of the depopulated zone with gate bias determined by our model, compared with those given by the one dimensional model [3], [9].

V. CONCLUSION

The simulation which we have realised, give the variation of the height of channel or the thickness of the depletion layer, with the variation of the tension apply to the gate and thus to control the current cross the component, and taking into account of geometry exact of component. Then we proved so the one dimensional [3], [9] model, give the results with a very low precision, specially for the high bias gate. We can use our results for determining the characteristics static for the field effect transistor (Like: capacities, resistance, conductance of channel …). That our results can contribute to the design of the field-effect transistors in planar technology, and by consequent reducing the manufacturing cost of the component.

REFERENCES


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