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NUMERICAL MODELING OF MICROWAVE PERFORMANCE FOR SUBMICRON GaAs MESFETs

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SUMMARY

Microwave performances of GaAs MESFETs with submicron feature sizes are investigated numerically in this work in order to get clear physical insight for device operation at microwave frequencies. Total Quantity of Carrier analysis method is implemented in our newly developed two-dimensional program to model carrier transport problems. Time-dependent carrier transport equations are coupled with carrier momentum and energy balance equations to take account velocity overshoot and saturation effects in submicron GaAs MESFETs. Microwave performances for GaAs MESFETs with device feature size ranging from 0.3 to 1.0 micron are calculated and good agreement between simulation and published experiment is obtained.

INTRODUCTION

The rapid progress in development of processing technology and improvement in material properties make GaAs MESFET one of the most promising microwave solid state devices. It is, therefor, important to develop an accurate model in order to reveal physical insight and predict the performance for submicron GaAs MESFETs operating at microwave frequancies. In our recent work (S.Xiao,1987), transient and high frequency performances for both GaAs and silicon FET with submicron dimensions have been successfully modeled by using Total Quantity of Carrier analysis method (C.Huang,1986). In this work, we extend this model for microwave analysis of submicron GaAs MESFETs.

NUMETICAL MODELING

As device feature size is reduced down to submicron range, it is noted that electron transit time is comparable with momentum relaxation time and velocity overshoot and velicity saturation effects can no longer be neglected.In our novel two-dimensional program, time-dependent carrier transport equations are coupled with a set of phenomenological equations to take these effects into accounts. These equations are:

$$\nabla \cdot F = \rho/\varepsilon \tag{1}$$

$$\frac{\partial n}{\partial t} - \frac{1}{q}\nabla \cdot j_n = G - R \tag{2}$$

$$\frac{dm(E)v}{dt} = -qF - \frac{mv}{\tau_p(E)} \tag{3}$$

$$\frac{dE}{dt} = \frac{j \cdot F}{n} - \frac{E - E_0}{\tau_E(E)} \tag{4}$$

$$j = -qnv + qD(E)\nabla n \tag{5}$$

where E is the average electron energy, m(E) is the effective mass of electron. E0=3/2K · T0, T0 is the lattice temperature. $\tau_p(E)$, and $\tau_E(E)$ are the effective momentum relaxation time and effective energy relaxation time, they are determined by following expressions (M.Shur, 1987):

$$\tau_p(E) = \left\{\frac{m[F(E)]v[F(E)]}{qF(E)}\right\}_{\text{steady state}} \tag{6}$$

$$\tau_E(E) = \frac{E - E_0}{q\{F(E)v[F(E)]\}_{\text{steady state}}} \tag{7}$$

A new algorithm, alternating-direction scheme, is used in the program for solving time-dependent transport equations. The general flowchart is shown in Fig. 1.

SIMULATION RESULTS

Shown in Fig. 2 is the illustration of electric field distribution for 0.3 µm GaAs MESFET. The two-dimensional silulation shows that electric field under the drain end of gate in a 0.3 µm GaAs MESFET is well above 5.0E4v/cm, critical value for velocity overshoot, and corresponding drift velocity is calculated to be about 9.0E7 cm/s,3 times

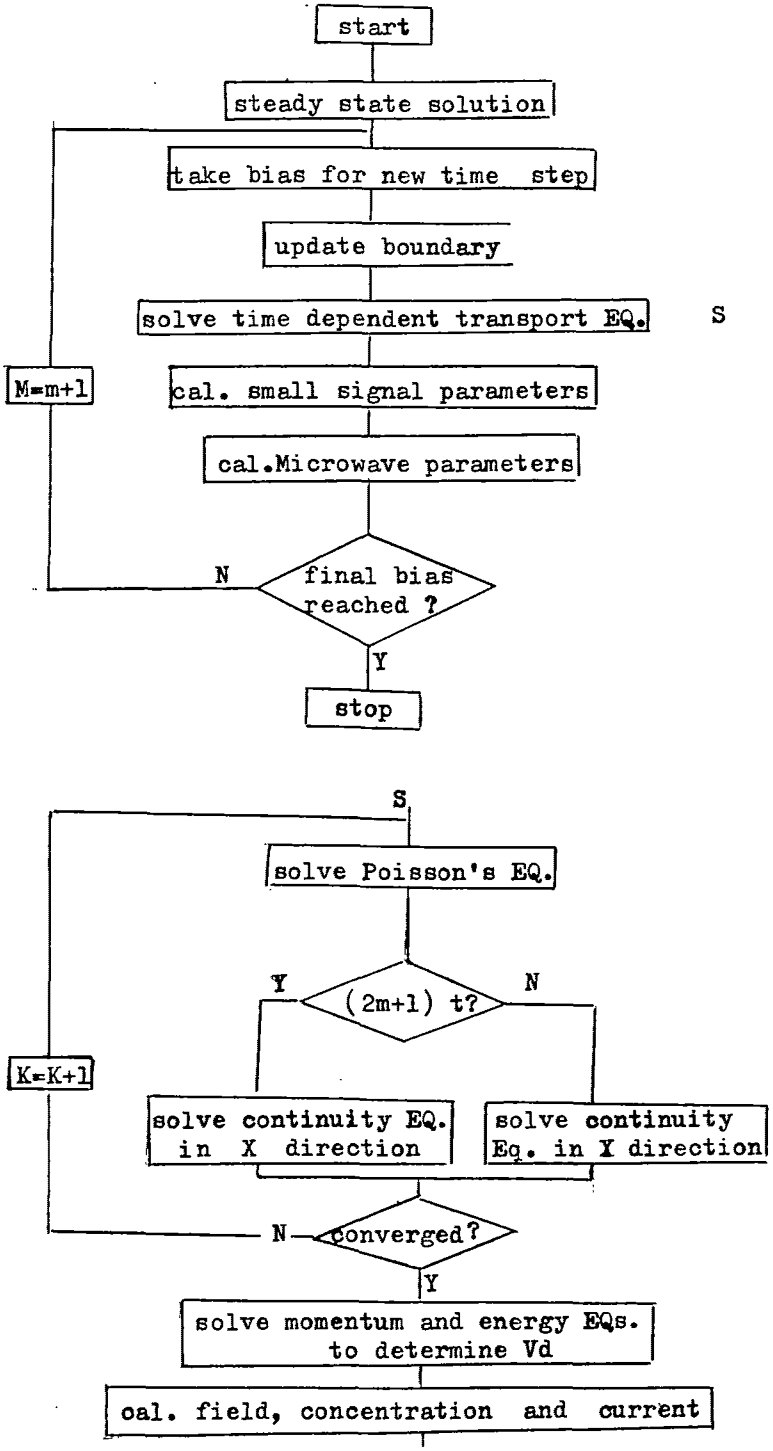


Fig. 1 General flowchart of microwave analysis program

as large as saturation velocity (J.G.Rush,1972).

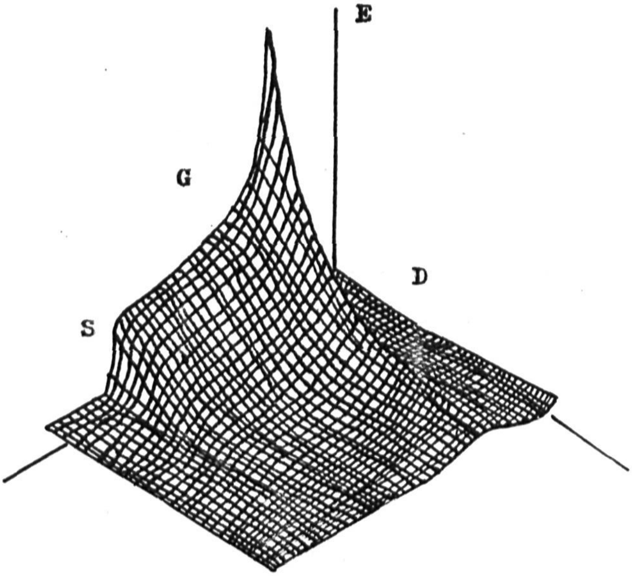
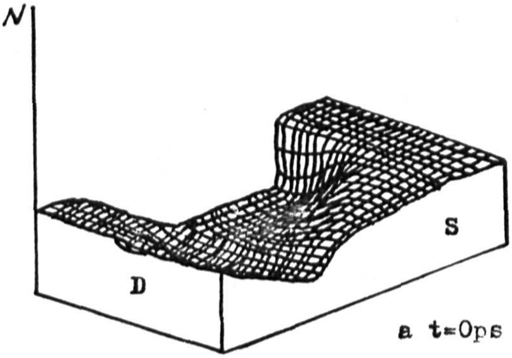


Fig. 2 Illustration of electric field distribution for 0.3 um GaAs MESFET



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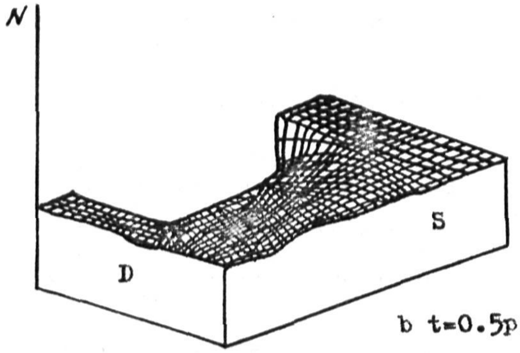

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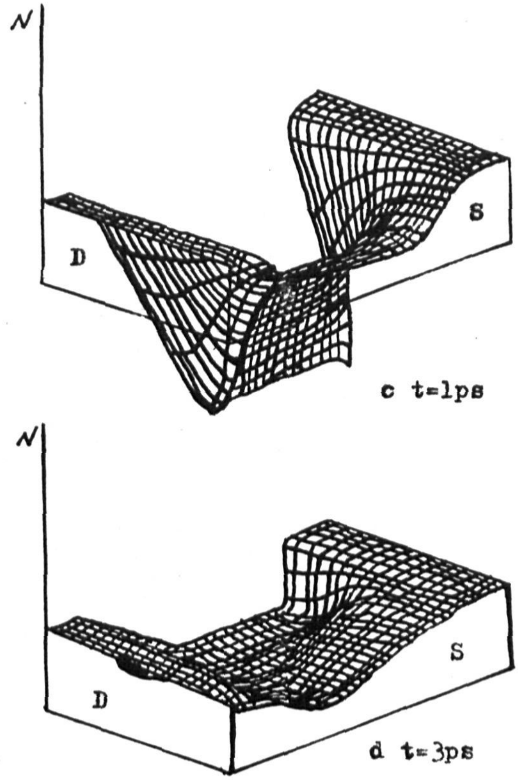

Fig. 3 Illustration of electron distribution

Using two-dimensional simulation, parasitic capacitance and other small signal parameters for different channel MESFETs are evaluated and their dependence on device active layer thickness and channel doping concentration is investigated. Minimum noise figure and associated gain vs frequency for 0.3 and 0.5 μm MESFETs are calculated based on simulation results and by following Fukul's work (Fukul,H, 1979), as shown in Fig.4. Coparison between these calculated results and published experiment (J.A. Turner,1982) shows good agreement.

Based on two-dimensional simulation, Maximum operation frequency for devices with different gate lengths are also predicted, this is shown in Fig. 5.

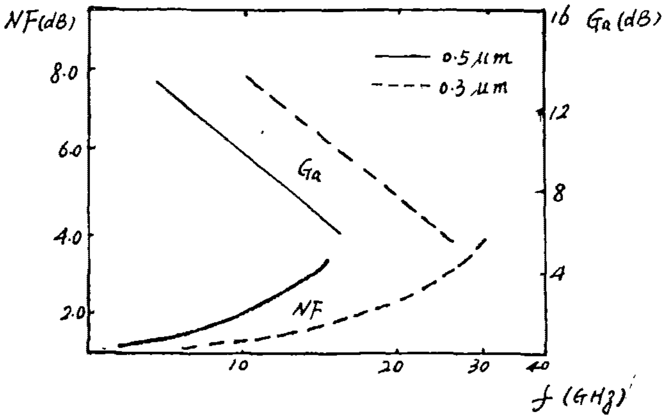

Fig. 4 Minimum noise figure and associated gain vs frequency for 0.3 and 0.5 um GaAs MESFETs.

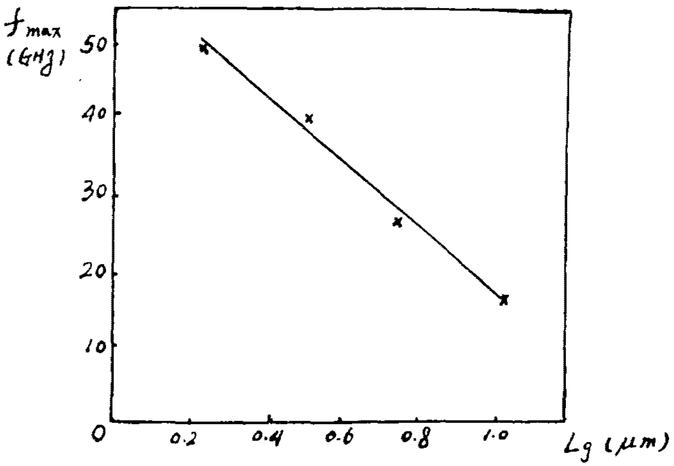

Fig. 5 Maximum operating frequency for GaAs MESFETs with different gate lengths.

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