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# Simulation for Submicrometer MOSFET

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ABSTRACT: A numerical model for simulating submicrometer MOSFET is developed by considering carrier energy transport and an improved carrier mobility model which is associated with energy relaxation time and quantum channel broaden effect. Numerical results match the experiment data very well.

## I. INTRODUCTION

With diminishing feature size of device structure towards submicrometer order and the increasing complexity of device operation, the use of computer simulation has proven to be valuable aids in development and characterization of ULSI device. However, the increasing complexity of device operation causes some problems. Carrier transport is not simply described by drift-diffusion theory, and the effect of energy transport on carrier behavior should be considered. Not only lattice scattering, impurity scattering, carrier-carrier scattering, surface scattering and veloicity saturation effect but also energy relexation time and quantum channel broaden will effect on carrier mobility. Yamaguchi's[1] has no cosideration of relaxation time and quantum channel broaden, H.Shin's[2] does not include energy transport and relaxation time effect.

It is obvious that a more accurate model for submicrometer MOSFET is required. A new numerical submicrometer MOSFET's model is presented in this paper. Based on all kinds of scattering mechanism,the effects of energy relaxation time and quantum channel broaden on carrier mobility are considered. The satisfactory results are obtained.

## II. MODEL.

A set of equations as follows is used to describ submicrometer MOSFET.

$$\nabla^2\psi = -\frac{q}{\varepsilon}(p-n+N) \tag{1}$$

$$\nabla\cdot\vec{J}_n = qR \tag{2}$$

$$\nabla\cdot\vec{J}_p = -qR \tag{3}$$

$$\vec{J}_n = q\mu_n n\vec{E} + K\mu_n\nabla(nT_n) \tag{4}$$

$$\vec{J}_p = q\mu_p p\vec{E} - K\mu_p\nabla(pT_p) \tag{5}$$

$$\nabla\cdot\vec{S}_n = \vec{J}_n\cdot\vec{E} - \frac{3}{2}Kn\frac{T_n-T_0}{\tau_{\epsilon n}} \tag{6}$$

$$\nabla\cdot\vec{S}_p = \vec{J}_p\cdot\vec{E} - \frac{3}{2}Kp\frac{T_p-T_0}{\tau_{\epsilon p}} \tag{7}$$

$$\vec{S}_n = -\frac{KT}{q}\delta_n(T_n)\vec{J}_n - \chi_n(T_n)\nabla T_n \tag{8}$$

$$\vec{S}_p = \frac{KT}{q}\delta_p(T_p)\vec{J}_p - \chi_p(T_p)\nabla T_p \tag{9}$$

(1) is poisson's equation, (2) and (3) continuity equations, (4) and (5) carrier transport equations,(6)and(7) energy balance equations,(8)and(9) energy transport equations. The mobility model is based on the model which was proposed by Hansch[3].

$$\mu = \frac{\mu_0 f}{1+\frac{3K\mu_0 f}{2q\tau_\epsilon v_s^2}(T-T_0)} \tag{10}$$

the equivalent form as follows:

$$\mu = \frac{2\mu_0 f}{1+\sqrt{1+\left(\frac{2\mu_0 f E_{\parallel}}{v_s}\right)^2}} \tag{11}$$

where

$$\mu_0 = \frac{\mu_L}{\sqrt{1+\frac{N}{N/S+N_{ref}}}} \tag{12}$$

$$f = 1/\left[1+P_1\alpha_1\mu_0 E_\perp/(1+\beta E_\perp^{2/3})\right] \tag{13}$$

Where $\alpha_1$=8.0x$10^{-8}$ s/cm, =3.18x$10^{-4}$ $(cm/v)^{-2/3}$ ,S=351,Nref=3x$10^{16}$$cm^{-3}$,Vs=1.0x$10^{7}$cm/s.$P_1$ is dependent on the surface state density and charge density in inversion layer, and is calculated by the formula from Schwarz[4].

## III. Numerical Results.

A program ETMOS is developed using present model. The 2-D results, which do not include energy transport,are used as initial values, and SIP iterative methode is implemented, the energy relaxation time is from 0.3 to 0.01ps.

Fig.1 shows the comparasion of present model and H.Shin's [2] with experiment data for the device Leff=0.9 um, $Na=1x10^{17}$ $/cm^3$, Weff=9.4 um, $Nf=3x10^{10}$ $/cm^2$. The better agreement of present model with experiment data is observed.

The comparasion of drift velocity of electron from present model with experiment data [5] is given in Fig.2. A very good match is also obtained. Fig.3 shows us energy Flux vs drain voltage. Fig.4 is the electron temperature distribution in device.

## IV. Summary.

A new numerical model for submicrometer MOSFET based on energy transport and considering the effect of energy relaxation time and quantum channel broaden on carrier mobility is a more accurate model. Numerical results fit experiment extremly well because it describes the operation of device more correctly.

## Refferences:

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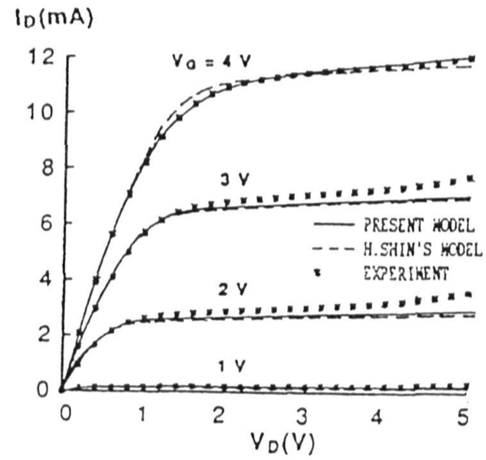


Fig.1. $I_D$ vs $V_D$ for Leff=0.9 um MOSFET's.

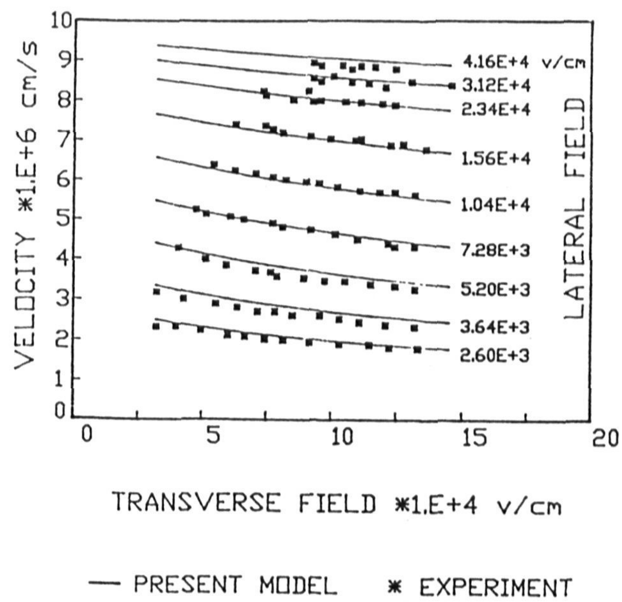


Fig.2. Electron Velocity vs Transverse Field.

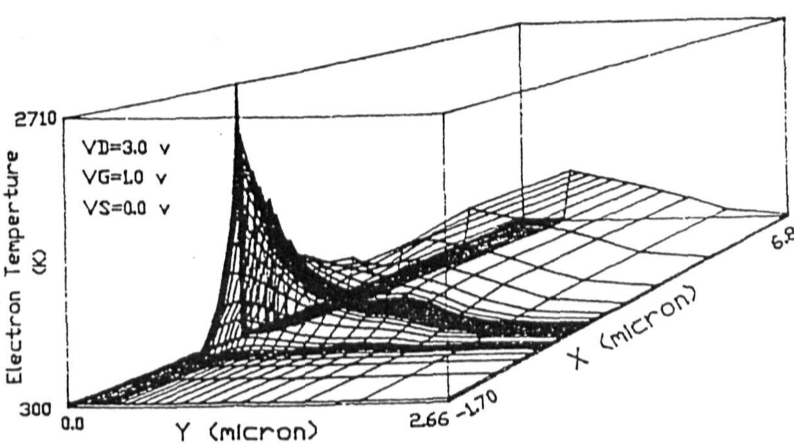


Fig.4. Electron Temperature Distribution.

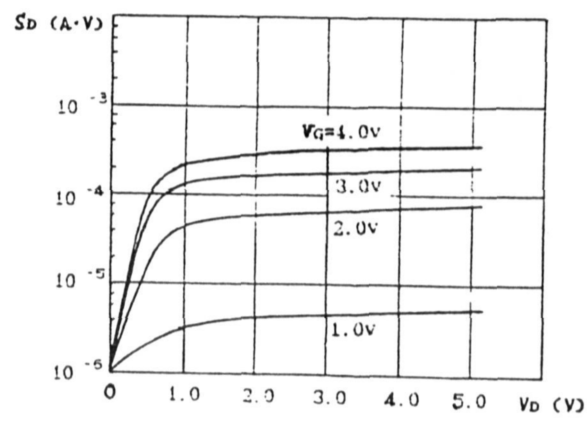


Fig.3. Drain Energy Flux vs Drain Voltage.