Description of the Electron Transport in Submicron GaAs MESFET's With the Effective Mobility Including Near Ballistic Transport

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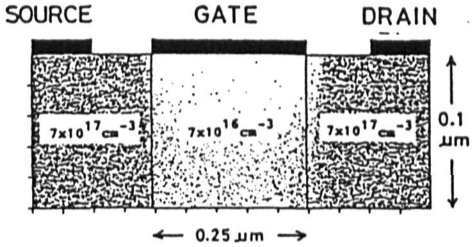
ABSTRACT-It has been found that the electron transport in the low-field region under the gate in a 0.25 um gate GaAs MESFET should not be expressed by the bulk mobility(μ_B), but by the effective mobility(μ_s) including the near ballistic transport.

SIMULATION RESULTS-The velocity-field(V-F) characteristics in the 0.25 μm gate GaAs MESFET have been evaluated under the gate using the particle simulator with an ensemble Monte Carlo technique(PS), which are shown in Fig. 1. We define the saturation velocity(v_s) and the effective mobility(μ_s) by v_s=0.8 v_{max} and $\mu_s = v_s/F_s$, respectively, where F_s is the saturation field corresponding to v_s. The properties of μ_s and v_s can be successfully expressed as functions of the average gradient of the distribution of electric field(A) in the low field region. Then μ_s decreases and v_s increases, as A increases(Figs. 2 and 3). These are caused from inertia of electrons in the near ballistic transport. The values of A are estimated by $A=F_s/\Delta z$, where Δz is the distance from the source n^+-n junction to the saturation point. Naturally the increase of A corresponds to that of the drain voltage(V_D). At V_D=1.0 V(A~20 V/μm^2) μ_s is about a half of μ_B(~6,300 cm^2/Vs). Thus, the dependence of μ_s on A is significant.

MODELING-The above properties of μ_s and v_s can be also predicted by a simple 1D relaxation time approximation(RTA) for a simplified model of a linearly graded distribution of electric field(F=Az). The V-F characteristics in Fig. 4 and the solid lines in Figs. 2 and 3 are numerically obtained by the RTA. The solid line for μ_s excellently agrees with the circles obtained by PS. Figure 5 illustrates a basic difference between the conventional and present models for the V-F characteristics using μ_s and v_s. It is stressed that the electron transport in the low-field region under the gate should not be expressed by μ_B, but by μ_s.

We have also derived simple analytical expressions for μ_s and v_s which are based on the RTA and introduced the expressions into an analtytical device model. Fig. 6 shows a comparison between the I-V characteristics obtained by the analytical model(—) and the simulation(○,●).



Schematic Drawing of GaAs MESFET's
(300K)

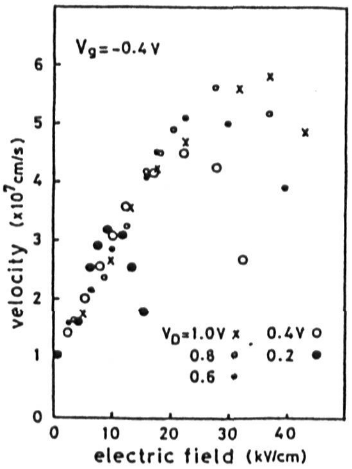


Fig. 1 V-F characteristics

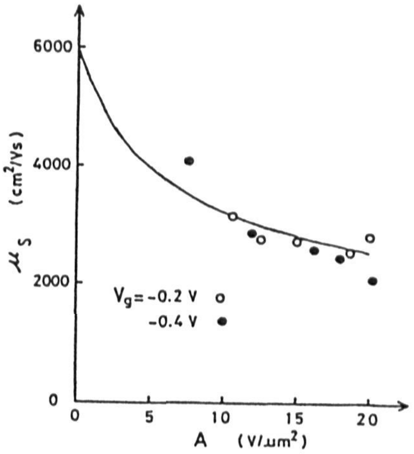


Fig. 2

Dependence of μ_s on A. Circles are obtained by PS and the line by RTA.

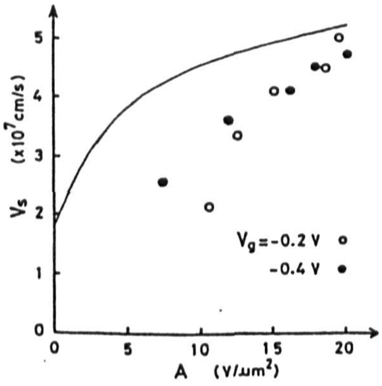


Fig. 3 Dependence of v_s on A. The notations are as same as those in Fig. 2.

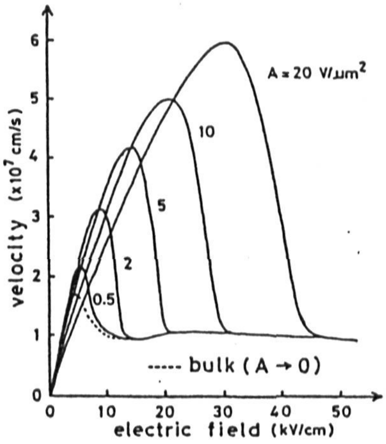


Fig. 4 Velocity-field characteristics obtained from the model distribution of electric field using 1D RTA.

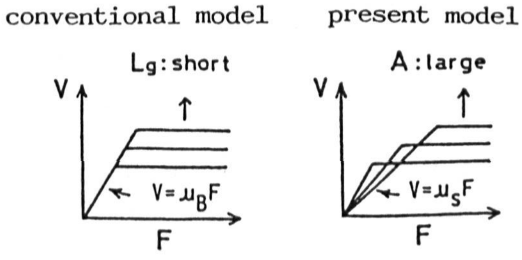


Fig. 5 Schematic drawings of the V-F characteristics using the mobilities and saturation velocity.

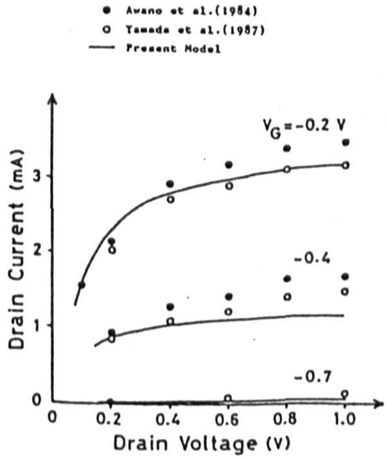


Fig. 6 Current-voltage characteristics.