DESIGN CONSIDERATIONS FOR SUBMICRON-SCALE GaAs MESFETs

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ABSTRACT

To obtain information for the design of GaAs MESFET's which are affected by velocity overshoot, a two-dimensional computer simulation which involves energy transport analysis of carrier dynamics has been carried out. The indices of performance $g_m$, $C_{gs}$, and $f_T$ are evaluated as functions of geometry, doping and applied bias and are compared with experimental data and the results of other hydrodynamic and Monte Carlo two-dimensional models. It is shown that the energy transport computer simulation used here can be a very useful CAD tool for optimizing the design of submicron-scale GaAs MESFET's.

INTRODUCTION

Computer simulation using particles is generally capable of accurately describing the microscopic dynamical processes within a device in which both the geometry and the device coupling with respect to its environment are complicated. However, due to computational cost (approximately 3 cpu hr/bias point on an IBM 370/195 for one program), such simulation cannot be widely used. Therefore, simpler hydrodynamic models, with transport coefficients fit to measured or simulated results, have been proposed. These hydrodynamic models, which are based on the Boltzmann or Langevin equations, and depend on the assumption that all important dynamical information can be described by the first few moments of the distribution function, are a reasonable compromise between physical details and engineering expedience.

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Most hydrodynamic models that have been proposed for studying velocity overshoot and related nonlinear phenomena in FET's, however, have used some rather drastic approximations. Typically these may include:

a) one-dimensionality
b) use of a gradual-channel approximation
c) assumption that carriers in upper valleys are not heated appreciably and that relaxation time is a constant in the energy transport equation
d) use of a "fixed" or "effective" velocity-field curve, with a conventional transport model
e) neglect of lattice scattering effects altogether ("ballistic" model)

We use here, however, an efficient algorithm for a two-dimensional hydrodynamic model which takes into account the important nonequilibrium and nonlinear transport dynamics of carrier transport in GaAs MESFET's, and which essentially avoids the approximations listed above\textsuperscript{13}. Compatibility of the results of this model with those of complete Monte Carlo simulations has been demonstrated\textsuperscript{13}, although such agreement does not in itself guarantee the accuracy of the model. The value of any efficient hydrodynamic model lies in its being able to correctly predict performance of a real device, or at least give the right trends as various design parameters are varied.

The purpose of the present work is twofold: first, to demonstrate the predictive ability of the two-dimensional energy transport model as applied to submicron-scale GaAs MESFET's, by comparing numerical simulation results with experimental data on real devices, with numerical values given by another simplified two-dimensional hydrodynamic model\textsuperscript{7}, with a calculation performed excluding velocity overshoot, and with a two-dimensional Monte Carlo simulation\textsuperscript{14}. Second, to discuss the implications of these results for the designers of submicron-scale GaAs MESFET's. Three devices, chosen to closely resemble reported real devices\textsuperscript{15-17}, are simulated here. These "devices" are tagged as MFT1 \((L_g = .25 \mu)\); MFT2 \((.6 \mu)\); and MFT3 \((1.0 \mu)\).

DEVICE GEOMETRY AND BOUNDARY CONDITIONS

The device geometry used in Reference 13 is used in all simulations, and, as there, contact space-charge effects are neglected. The source and drain boundary regions in this model serve mainly to define the regions existing between source and gate and between gate and drain. Both Monte Carlo and Prussian simulations show these regions, in which the electron potential settles down to the source and drain electrode potential values, are typically rather