EPSRC GRANT GR/J41642 **FINAL REPORT**

MODELLING OF HEMTs AND MESFETs

Summary

This grant was awarded to Professor R A Abram in August 1993 to carry out research on the modelling of High Electron Mobility Transistors (HEMTs) and Metal Semiconductor Field Effect Transistors (MESFETs) using the Monte Carlo method. The main objectives of the research were to develop two-dimensional, selfconsistent, Monte Carlo-based simulations of HEMTs and MESFETs that included (i) the gate recess, (ii) the true structure of source and drain electrodes, and (iii) surface states, and to apply the simulation to study state of the art HEMTs and a new generation of high performance GaAs MESFETs. The research grant provided funds for an HP735 workstation and one postdoctoral assistant for three years.

The Monte Carlo software written for the simulations was developed in collaboration with concurrent device modelling projects concerned with HBTs (GR/H45094) and semiconductor lasers (GR/J10495) which also made extensive use of Monte Carlo techniques. As a result a general Monte Carlo subroutine library has been constructed that can be applied to devices of arbitrary geometry and has served all three projects. The package is called the software library for universal random particle simulation (SLURPS), and is one of the major achievements of the project. Versions have been supplied to DRA (Malvern), GEC-Marconi Materials Technology (Caswell) and the Computational Condensed Matter Physics Group at the University of East Anglia.

One of the main applications of SLURPS in this project has been the investigation of the response of field effect transistors to very high frequency signals and specifically those close to the cut off frequency f_T. One particular device studied was a 50 nm gate delta doped AlInAs/InGaAs PHEMT with a 0.25 μm source - drain separation. This very short gate device was reported to have an intrinsic cut-off frequency of 740 GHz. The high f_T of the transistor allowed a direct simulation of the effect of sinusoidal signals applied to the gate to give information on the modulation response of the device on both microscopic and macroscopic scales at frequencies of normal operation. Using the results of these simulations it has been possible to explain the microscopic behaviour of the electrons and the contact currents with reference to the spatial and temporal variation of the conduction band edge and the conduction and displacement current densities within the transistor.

Another theme has been the consideration of MESFETs whose high frequency performance is comparable to HEMTs but retain the advantage of being more straightforward to fabricate. The basic approach is to achieve by doping, rather than by use of a heterostructure, the thin channel and high carrier concentration which are important in realising the performance of a HEMT. We have carried out studies of a number of device structures to compare the microscopic processes in HEMTs and MESFETs and to assess the potential for enhanced performance in the latter.

SLURPS is based on semiclassical carrier dynamics but as a first step towards the inclusion of quantum mechanical effects in real device simulations we have also carried out some research on a quantum mechanical description of real and reciprocal space transfer at a simple quantum well.

Professor R A Abram
Department of Physics
University of Durham

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