MINIMOS-NT: A GENERIC SIMULATOR FOR COMPLEX SEMICONDUCTOR DEVICES

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MINIMOS-NT, a generic device simulator is presented. This simulator is capable of dealing with complex device geometries as well as with several physical models represented by certain sets of partial differential equations. A description of the structure of the simulator is given, which shows the basic idea of splitting the device geometry in distinct regions. Within these "segments", arbitrary material properties and physical models, i.e. partial differential equations, can be defined independently. The segments are linked together by interface models which account for the interface conditions. The emerging linear system can be solved by a Gauß-solver or by a state-of-the-art BiCGStab algorithm. Two examples, an n-channel CCD and a quarter micron low-noise HEMT, conclude the explanations.

1 Introduction

The recent advances in development of semiconductor devices tend to more and more complex device structures. This concerns device geometry as well as the combination of different materials. For instance, high electron mobility transistors (HEMT) have conquered the area of high frequency applications. These transistors are built from several layers of semiconductor alloys to obtain a channel with high electron mobility. But also BiCMOS devices or CCDs show complex device geometries. This provides new challenges on device simulation.

Our new device simulator MINIMOS-NT is based upon modern software concepts to comply with these demands. Object-oriented algorithms are featuring discretization and equation assembly. These concepts hold for two dimensions as well as for three dimensions in space.

2 Structure

The basic idea to handle complex device structures is to partition the geometries in independent regions, so called segments, for which different sets of parameters, models, and algorithms can be defined. This results in high flexibility which allows, e.g., to use a hydrodynamic model on one segment and a drift-diffusion model on another segment. Also, different discretization schemes are possible, hence triangular and rectangular grids can be combined, that need not even be conform, i.e., neighboring segment grids need not have common interface points.

Interface conditions link the segments together and make it possible to consider, e.g., heterojunction interfaces with abrupt changes of parameters, such as band-edge energies. Therefore the standard interface conditions are imposed by a thermionic emission model.

The linear system is solved either by a Gauß-solver or by a state-of-the-art BiCGStab algorithm. When the BiCGStab algorithm is employed, at first the matrix is automatically scaled with an iterative algorithm1). Furthermore, a block-iterative algorithm which solves Possion's equation and continuity equation iteratively with the set consisting of continuity and energy balance equations improves the moderate convergence typically observed with the hydrodynamic model. The final accuracy is then obtained by a few full Newton schemes.

Even though the simulator is a stand alone program, it is fully integrated into the VISTA framework$^{2)}$. Thus, MINIMOS-NT is coupled to all framework tools, such as visualization and geometry editor, as well as to device and process simulators available within VISTA.

3 Examples

Two examples are presented to demonstrate the capabilities stated above. A three-phase clock, n-channel CCD consisting of 15 gates has been simulated in two space dimensions (see Fig. 1). The source and drain contacts were held constant at 0V, the bulk contact at −1V.

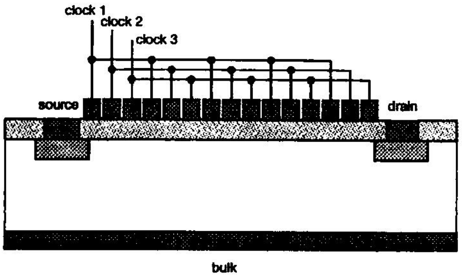

Figure 1: Structure of the CCD

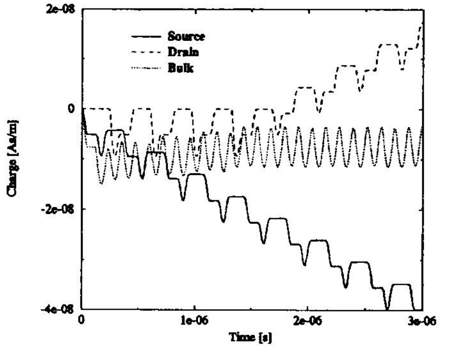

Figure 2: Charge passed through the contacts of a 15 gate CCD

The voltages applied to the gates varied between −1V and +5V. The simulation over ten clock periods required 360 time steps. The adapted space grid consisted of approximately 10,000 points. For the transient integration a predictor-corrector method was found to be most suitable for the problem. Fig. 2 shows the integrated contact currents, i.e., the charges passed through the contacts.

The second example is the hydrodynamic simulation of a quarter micron gate-length low-noise HEMT. Fig. 3 shows the the structure of the device and the electron temperature with a significant peak at the drain-sided end of the channel ($V_{DS} = 5V$, $V_{GS} = 1V$). The output characteristics are plotted in Fig. 4.

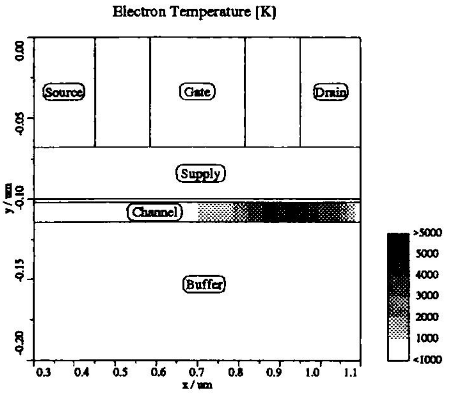

Figure 3: Carrier temperature of the low-noise HEMT ($V_{DS} = 5V$, $V_{GS} = 1V$).

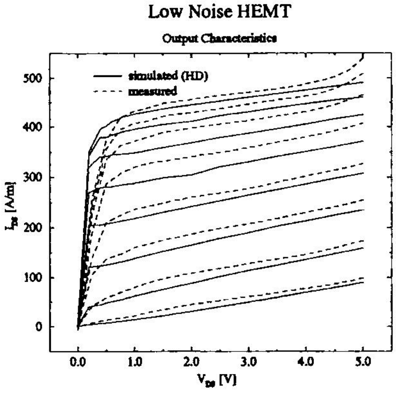

Figure 4: Output characteristics of the low-noise HEMT

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