Simulation of Line-Doping-HEMTs by a Coupled Solution of the Schrödinger Equation with a Macroscopic Transport Model

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The simulation of line doping HEMT structures offers expanding possibilities for the understanding of the inner electronic characteristics of such devices. These structures are experimentally investigated at the Ruhr University Bochum. For the simulation the 2D/3D device simulator SIMBA is used, which is capable of dealing with complex device geometries as well as with several physical models represented by certain sets of partial differential equations. Together with a multidimensional solution of the Poisson equation the Schrödinger equation is solved either in one or in two dimensions according to the confinement of the electrons in the area where quantum mechanical effects are expected. Schrödinger equation, Poisson equation, and carrier continuity equations, both for electrons and holes, are solved self-consistently in a nested iteration algorithm. High-order models like energy balance equations are neglected in this case because of the high computation times.

Results and Device Performance

At first the gate structure of the line doping HEMT (Fig. 1a) is simulated for different line breadths (d_l) to understand the characteristic of the carrier density distribution. The aim of these investigations is the creation of a quasi 1-dimensional electron gas, which is used for the carrier transport in the line doping HEMT. Fig. 2 show the maximum electron density in the channel region for different line breadths (d_l). A decrease of the carrier density at very small line breadths can be detected. Furthermore the inner electronic behavior of a HEMT with two doping lines is calculated (Fig. 3) and the distances (d) between the lines as well as the line breadths are varied. The electron distribution in y-direction for different distances (d) and d_l = 100 nm of the doping lines is represented in Fig. 4. By a combination of doping lines (d_l = 200 nm) the maximum electron density was obtained.

Fig. 1b shows the cross-section of the SPS-HEMT with one doping line for the corresponding gate structure (Fig. 1a). These calculations request a real 3D simulation. The reason is the carrier confinement in x- and y-direction and consequently a carrier flux along the interface between the AlGaAs doping line and the GaAs buffer in z-direction. First simulations of this structures show a carrier confinement in two directions and a small carrier density. Fig. 5 and 6 show the calculated output and transfer characteristics respectively. The maximum transconductions $g_{m,max}$ = 40 µS is obtained at the bias point V_{GS} = 0.75 V, V_{DS} = 1.0 V. The statement of the small current values is the strong carrier confinement as well as small-scale numbers of electrons by a quasi 1-dimenional electron gas.

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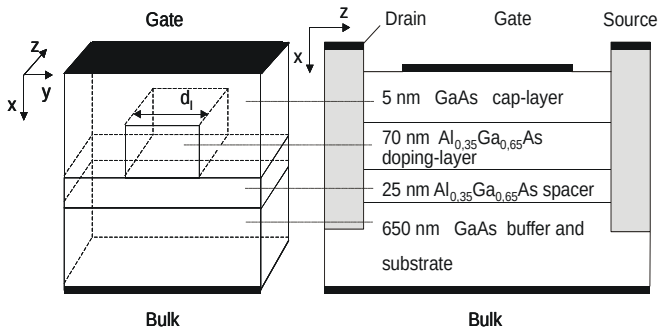

a) **b)**

Fig. 1 **Structure of the line doping SPS-HEMT**

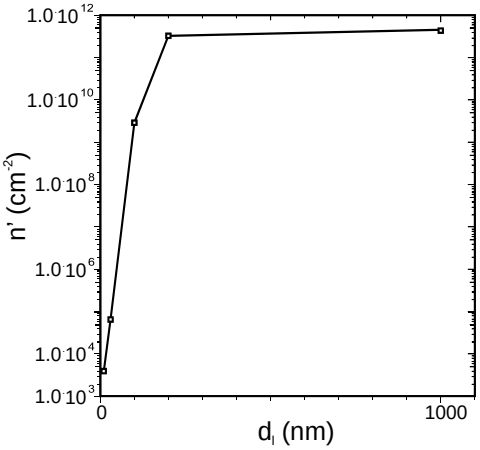

Fig. 2 **Electron sheet density as function of the line breadth (d_l)**

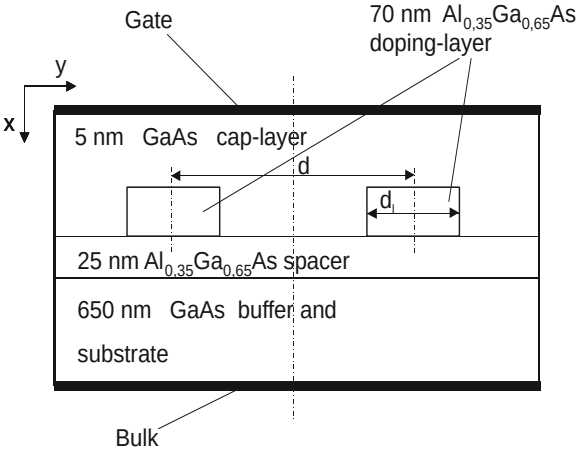

Fig. 3 **Gate structure of the SPS-HEMT device with two doping lines (cross-section)**

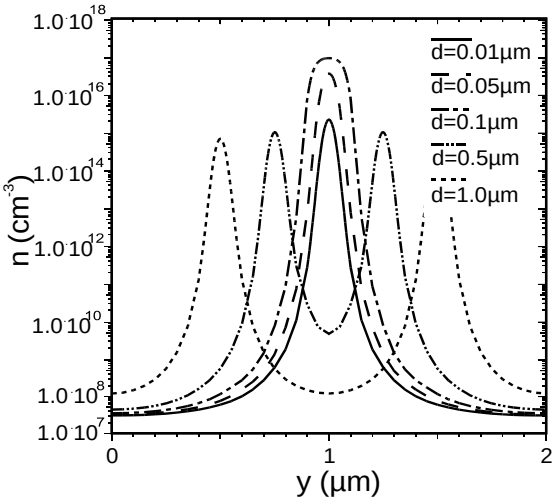

Fig. 4 **Electron density distribution in y-directions for two doping lines (d_l = 100 nm)**

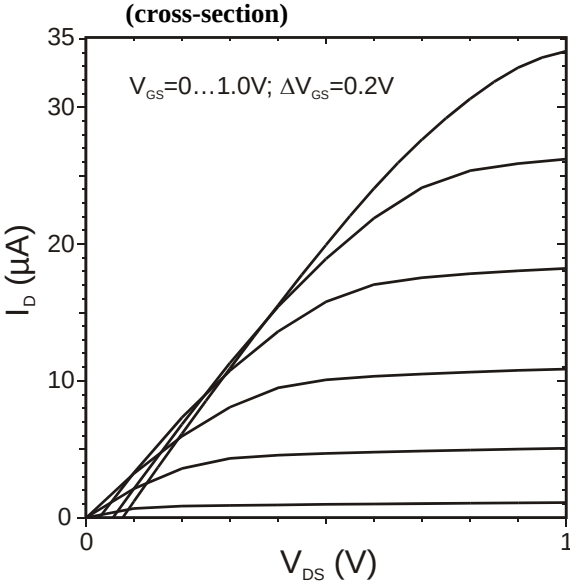

Fig. 5 **Output characteristics**

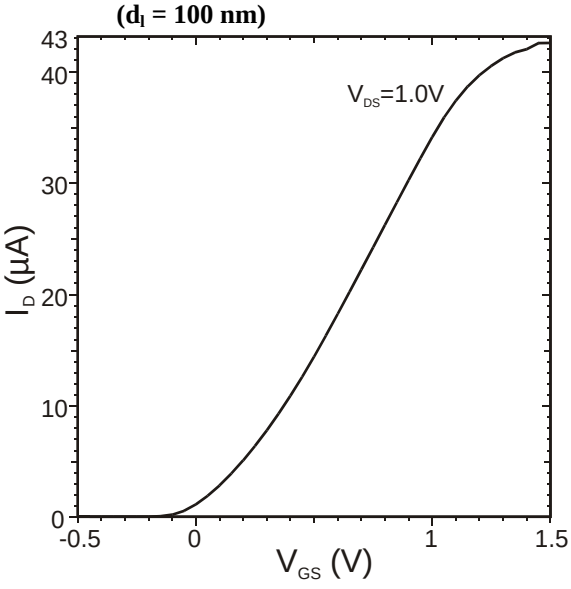

Fig. 6 **Transfer characteristic**