Monte Carlo Algorithm for Mobility Calculations in Thin Body Field Effect Transistors: Role of Degeneracy and Intersubband Scattering

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We generalize the Monte Carlo algorithm designed for small signal analysis of the three-dimensional electron gas to quasi two-dimensional electron systems. The method is based on the solution of the linearized Boltzmann equation and is exact in

the limit of negligible driving fields. Contrary to standard Monte Carlo methods to simulate transport, the Monte Carlo algorithm takes naturally into account the fermionic nature of electrons via the Pauli exclusion principle. Degeneracy effects due to the Pauli exclusion principle play an important role at high inversion layer carrier concentrations. The method allows inclusion of arbitrary scattering mechanisms and band structure models and can be used in multi-valley and multi-subband cases.
The theoretically derived algorithm has a clear physical interpretation. The diffusion tensor is calculated as an integral of the velocity autocorrelation function. The mobility tensor is related to the diffusion tensor via the Einstein relation for degenerate statistics. We demonstrate the importance of degeneracy effects by evaluating the low-field mobility in contemporary field-effect transistors with a thin silicon body.
We show that degeneracy effects are essential for the correct interpretation of experimental mobility data for field effect transistors in singe- and double-gate operation mode. In double-gate structures with (100) crystal orientation of the silicon film degeneracy effects lead to an increased occupation of the higher subbands. This opens an additional channel for elastic scattering. Increased intersubband scattering compensates the volume inversion induced effect on the mobility enhancement and leads to an overall decrease in the mobility per channel in double-gate structures.