Quantum Correction to the Semiclassical Electron-Phonon Scattering Operator

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Boltzmann equation was successfully used for transport description and modeling in conventional semiconductor devices from the early development of semiconductor technology. Due to a rapid down scaling of transistor dimensions, with the 90 nm technology node being already industrially implemented, quantum effects becomes more pronounced, and the question of going beyond the semiclassical approach becomes increasingly relevant. An attractive approach which accounts for the quantum effects explicitely is based on the equation for the Wigner function. Similarly to the classical distribution function, the Wigner function depends on position and momentum simultaneously. Another attractive feature of the Wigner function approach is that the Boltzmann scattering integral may naturally be included to account for dissipative processes. It allows to treat semiclassical collisions on equal footing with the quantum mechanical interference effects, described by the quantum collision operator. The question, however, rises as to whether the use of the classical Boltzmann scattering operator in the Wigner equation is justified. It is well known that the Boltzmann scattering integral neglects several quantum mechanical effects such as collisional broadening due to the finite lifetime of single particle states, collisional retardation due to the finite collision time, and intra-collisional field effects.

To incorporate quantum effects due to the finiteness of the scattering duration we adopt the aforementioned quantum kinetic equation approach. For a spatially uniform system, the Levinson equation describes the interaction of a single electron with

an equilibrium phonon bath. We analyze a quantum correction to the semiclassical solution for the electron distribution function obtained by an asymptotic expansion for the quantum collision operator. Based on this expansion, a Monte Carlo algorithm is developed. The algorithm allows the calculation of the quantum correction to the distribution function *simultaneously* with the solution of the Boltzmann equation, which is a significant advantage as compared to previously used techniques.