Single Electron Dynamics in Semiconductor Nanostructures

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Recent progress on nanofabrication and high-frequency measurement allows us to study dynamical behavior of single-electron and its spin in semiconductor nanostructures. Quantum states in quantum dots can be manipulated with external voltage pulses, and can be measured by a point contact charge detector with wide bandwidth. With these techniques, we discuss coherency, dissipation and correlated transport in semiconductor quantum dots.

First, we discuss coherency of charge states in a double quantum dot [1]. Consider a two-level system, in which an excess electron occupies the left dot or the right dot. When these two states are coupled with a tunneling barrier, one can induce coherent charge oscillations by means of non-adiabatic excitation with a high-speed voltage pulse. The observed coherent charge oscillations are consistent with density-matrix calculations taking into account tunneling to the electrodes. The charge qubit can also be manipulated arbitrarily by tailoring the pulse waveform [2]. Although the obtained decoherence time of about 1 ns is relatively short at present, the experiments indicates the potential for controlling decoherence in nanostructures.

Second, we also discuss about dissipation in a quantum dot. We investigate the energy relaxation process from an excited state to the ground state in order to study relaxation mechanisms [3]. When the relaxation does not involve spin-flip, electron-phonon coupling of deformation and piezo-electric types dominates the relaxation time. In contrast, spin-flip relaxation time is 4-5 orders of magnitude longer than momentum relaxation time. We discuss interplay between cotunneling effect and spin-orbit coupling effect as spin relaxation mechanisms [4].

Lastly, we talk about charge detection measurement of a double quantum dot [5]. In contrast to conventional transport measurement, charge detection measurement allows us to detect single-electron within a relatively short time. This technique can be applied to measure an extremely small current by directly counting electrons. Actually a quantum point contact is used to detect individual single-electron tunneling events. Statistical analyses such as forward recurrence time and higher order moment noise indicate correlated transport for single-electron transport.

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