Manipulation of Electron Spin and Nuclear Spin in Double Quantum Dot System

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Electronic configuration in semiconductor quantum dots is tunable with various parameters such as plunger gate voltage, source-drain voltage and magnetic field. This makes quantum dots useful for investigating the novel electronic properties of confined, interacting electronic system. The electronic properties often appear strongly spin-related because spin is a well defined quantum number but sensitive to many-body correlations. In addition, we have recently observed for semiconductor quantum dots that the degree of electron-spin freedom is well isolated from the environment and also that the electron-spin is significantly influenced by exchange type interactions. These features imply that electron-spin in semiconductor quantum dots is a good candidate for implementing solid state spintronics including quantum computation. In this talk I will review experimental studies for controlling over electron-spin effects in coupled two-quantum dot system and manipulating hyperfine coupling between the electron-spin and nuclear-spin.

Electron transport is generally restricted by Pauli exclusion, which prevents two electrons from occupying the same state. I will first show that combined Pauli exclusion and Coulomb blockade can lead to rectification of single electron tunneling current in a series double dot system when the tranport occurs through the two-electron states. This current rectification is associated with the formation of a spin triplet state in the double dot, and the triplet state is relaxed by flipping an electron-spin via flip-flop hyperfine interaction. The spin flip-flop process significantly accumulates a nuclear-spin field because of the long relaxation time (T1). I will then show that the hyperfine coupling efficiency is tunable with souce-drain voltage as well as magnetic field. Using this technique, we manipulate the nuclear spin polarization to demonstrate a memory operation.