Resistive read-out of nuclear spin signals from a single quantum dot under the Kondo effect regime

Minoru Kawamura [1], Daniel Gottwald [1], Keiji Ono [1], Tomoki Machida [2, 3] and Kimitoshi Kono [1]

[1] *RIKEN, Japan*
[2] *Institute of Industrial Science, University of Tokyo, Japan*
[3] *Institute for Nano Quantum Information Electronics, University of Tokyo, Japan*

We study dynamic polarization and resistive detection of nuclear spins in a single quantum dot (QD) under the Kondo effect regime. We find that the differential conductance dI/dV_{sd} spectra of the QD exhibit remarkable hysteresis under the Kondo effect regime in magnetic fields when the bias voltage V_{sd} is scanned in the positive and negative directions (Fig. 1a). We also find that dI/dV_{sd} increases slowly under a fixed V_{sd} where the hysteresis is observed. Relevance of nuclear spins to the hysteresis and the slow increase in dI/dV_{sd} is unambiguously confirmed by the detection of nuclear magnetic resonance signals by monitoring dI/dV_{sd} under the irradiation of rf-magnetic fields. We attribute the origin of the hysteresis to the dynamic nuclear spin polarization (DNP) in the QD. Because the DNP develops during the scans of V_{sd} in the dI/dV_{sd}-V_{sd} measurement, the resultant difference in the effective magnetic field causes the hysteresis in the dI/dV_{sd}-V_{sd} curves.

Impact of the newly developed technique for the dynamic polarization and resistive detection of nuclear spins is further emphasized by the following nuclear spin relaxation rate $1/T_1$ measurement. Because $1/T_1$ is enhanced by the electron spin fluctuation, electron spin dynamics in the QD can be studied through the $1/T_1$ measurement. We find that the value of $1/T_1$ suppressed at around $V_{sd} = 0$ μV increases steeply with increasing V_{sd}, suggesting a bias-voltage-driven crossover from a spin-fixed state to a spin-fluctuating state (Fig. 1b). The crossover is one of unique features of the non-equilibrium Kondo effect under a magnetic field and is directly observed for the first time in the present study [1].

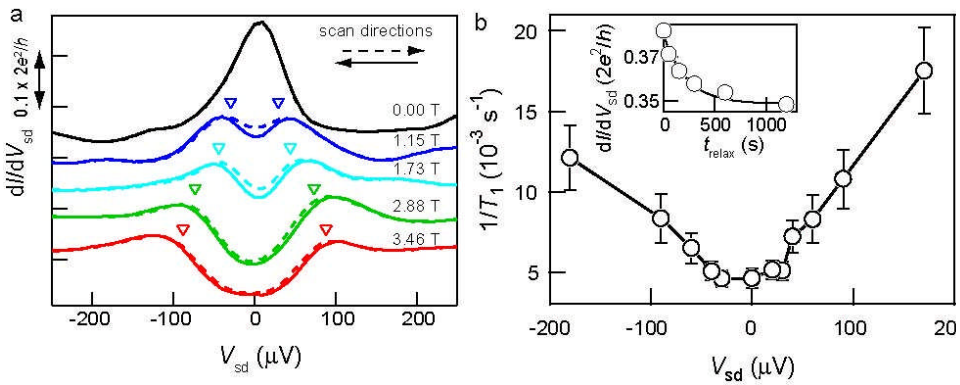

FIG. 1: (a) Differential conductance spectra of a QD under Kondo effect regime under variou magnetic fields.The curves are offset for clarity. (b) Bias voltage dependence of nuclear spi relaxation rate at $B = 2.88$ T. Inset shows a representative nuclear spin relaxation curve.

[1] M. Kawamura, D. Gottwald, K.Ono, T. Machida, and K. Kono, Phys.Rev. B **87**, 081303(R), 2013.