Nuclear Spin Related Measurements for Semiconductor Quantum Systems

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Recent progress of resistively-detected nuclear-magnetic-resonance (RDNMR) provides us a versatile tool to study physics in semiconductor quantum systems. The RDNMR needs nuclear polarization and sensitive detection of a change in nuclear polarization. In GaAs two-dimensional systems, the dynamic nuclear polarization (DNP) is achieved by a current flow through a domain structure appearing in the quantum Hall ferromagnet (QHF) at the spin phase transition of $\nu = 2/3$ or a quantum Hall breakdown regime. The situation necessary for the DNP enables us sensitive detection of the nuclear polarization.

Many interesting physics of two-dimensional system are clarified from RDNMR measurements. The Knight shift provides us information of electron spin polarization and/or charge/spin ordering. The electron spin polarization in the ground Landau-level (LL) deviates from a single particle picture, reflecting electron interaction and fractional quantum Hall effects (FQHE). It is noteworthy that the spin polarization does not follow a single particle picture even at the temperatures where FQHE disappears, suggesting temperature robust electron interaction in the ground LL.

The RDNMR study has also been extended to one-dimensional channel. Rich characteristics including change of RDNMR signal from dip (peak) to dispersive line-shapes are demonstrated by using triple-gate quantum point contact (QPC) where one-dimensional confinement can be manipulated precisely. The RDNMR results suggest where scattering between edge-channels happens near the constriction. It is also interesting that a quadrupolar splitting provides us information of the strain in the electron channel.

Finally, a microscopic imaging of nuclear spin resonance has been developed by a combination of the RDNMR and a sophisticated scanning-nanoprobe system operating at dilution temperatures. A quadrupolar coupling enables us rf electric field manipulation of nuclear spins. This manipulation has an advantage of a good spatial resolution without unintentional background compared with the conventional nuclear resonance based on rf magnetic field. Successful mapping of NMR signal intensity and Knight shift deepenes our understanding of the quantum Hall breakdown.