Local detection of nuclear spin resonance in a quantum-Hall-related system

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In quantum Hall (QH) related systems [1], strong interaction between a two-dimensional electron gas (2DEG) and nuclear spins provokes current-induced nuclear spin polarization. Resulting polarized nuclear spins are expected to be inhomogenously distributed due to correlation with the electron spins. We performed local detection of the resistively-detected nuclear spin resonance (NSR) using scanning gate microscopy technique.

The bottom panel shows an atomic force microscopy (AFM) profile taken along a line across a Hall bar which contains a 20-nm GaAs/$Al_{0.3}Ga_{0.7}As$ quantum well. Nuclear spins of the host materials are polarized within the Hall bar using the current-induced nuclear spin polarization in the QH effect breakdown [2], which was induced by applying a large source-drain current I_{sd} = 370 nA at a filling factor $\nu \sim 1$. During the AFM measurement, we applied a radio frequency (RF) bias voltage to the AFM tip with measuring the longitudinal resistance R_{xx}. We found clear drops in R_{xx} at the fundamental NSR frequency of ^{75}As nuclei $f = f_{75As}$ as well as a subharmonic frequency $f = f_{75As}/2$. The observed reduction in R_{xx} (ΔR_{xx}) is plotted in the upper panel as a function of the corresponding position depicted in the AFM profile (bottom panel). The f_{75As}-detected ΔR_{xx} (upper curve) contains a back ground of about 30 Ω at the positions well away from the Hall bar and it gradually increases toward to the Hall bar. In contrast, the $f_{75As}/2$-detected ΔR_{xx} (lower curve) sharply increases near the edges of the Hall bar from a zero back ground. We speculate that the application of the RF bias to the tip leads to two different NSRs. The key NSR is locally induced by the RF electric field beneath the tip [3]. Another occurs even at a distance from the tip due to an unintentional RF magnetic field which spreads over the sample, e.g., from the bias line connected to the tip. The former may arise at both $f = f_{75As}$ and $f_{75As}/2$ due to an electron-spin-mediated NSR [4], while the latter arises only at $f = f_{75As}$ as same as the conventional magnetic NSR. Thus, the $f_{75As}/2$ detection allows us to probe the nuclear spins, polarized within the Hall bar, at a higher resolution without the back ground.

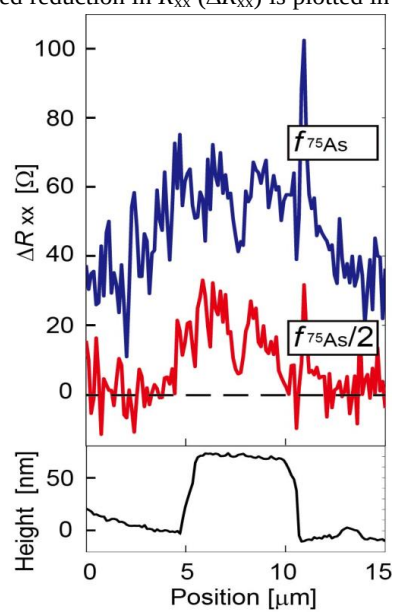

Fig. Local NSR (ΔR_{xx}) profiles measured with applying a RF voltage to the local gate at $f = f_{75As}$ (upper curve) and $f_{75As}/2$ (lower curve) along a line across the Hall bar (See AFM profile in bottom panel); temperature T = 160 mK, static magnetic field B = 8 T; the dashed line: $\Delta R_{xx} = 0$.

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