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Spin Dependent Transport in Narrow Gap $In_{0.75}Ga_{0.25}As/In_{0.75}Al_{0.25}As$ Heterostructure

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Recently a new field that has come to be called 'spintronics' is growing interest dramatically. In 1980, spin polarized field effect transistor (Spin-FET) was proposed by S. Datta *et al* [1], but not yet demonstrated. For this spintronic device essential requirements are two things, (i) modulation of spin precession angle induced by spin-orbit interaction, and (ii) efficient spin injection and detection from ferromagnetic metal into two dimensional electron gas (2DEG).

In this study, we investigated modulation of spin-orbit interaction and spin injection from ferromagnetic metal to 2DEG for realizing Spin-FET.

We prepared a layer structure of $In_{0.75}Ga_{0.25}As/In_{0.75}Al_{0.25}As$ modulation doped heterostructure by MBE, which had a sheet electron density $n_s=7\times10^{11}$ (cm^{-2}), and electron mobility $\mu_e=2\times10^5$ (cm^2/Vs) from Hall measurements at 4.2K. For determination of spin-orbit interaction parameter, we fabricated Hall-bar samples with gate and measured Shubnikov-de Haas oscillations with AC lock-in technique at 1.5K. Maximum value of spin-orbit interaction parameter, α_{zero}, obtained here is 32($\times10^{-12}$ eVm), and spin-splitting energy, Δ_R, is nearly 10meV. We confirmed gate-voltage control of α_{ZERO} in normal-type $In_{0.75}Ga_{0.25}As/In_{0.75}Al_{0.25}As$ heterostructure. α_{zero} was varied from 32($\times10^{-12}$ eVm) to 14 by applied negative gate voltage from 0 (V) to -6.0 (V).

We also carried out spin injection experiments using multi-terminal (non-local) geometry structure, this non-local transport coefficient is free from background signals unrelated spin injection [2]. We fabricated spin-injection samples, which had ferromagnetic electrodes ($Ni_{40}Fe_{60}$ width=F1:0.5 and F2:3μm apart from 1 or 3μm) deposited on $In_{0.75}Ga_{0.25}As$ besides a mesa. We observed that spin valve effect for source-drain resistance of ~0.1% and the hysterisis behavior of ~12% in non-local resistance at 1.5K. Both signatures disappeared at 190K. It is thus strongly suggested that the hysterisis behavior could not be explained only by local Hall effect, since n_s in our heterostructure is almost kept constant from 1.5K to 200K.

The origin of the large hystresis behavior has not yet been determined, but we could mention that it is not caused by local Hall effect but by spin related transport. It is plausible that the large zero-field spin-splitting unique to our heterojunction could enhance spin related phenomenon.

Reference

[1] S. Datta, and B. Das, Appl. Phys. Lett. 56, 665 (1990).
[2] P. C. van Son, H. van Kempen, and P. Wyder, Phys. Rev. Lett. **58**, 2271 (1987).

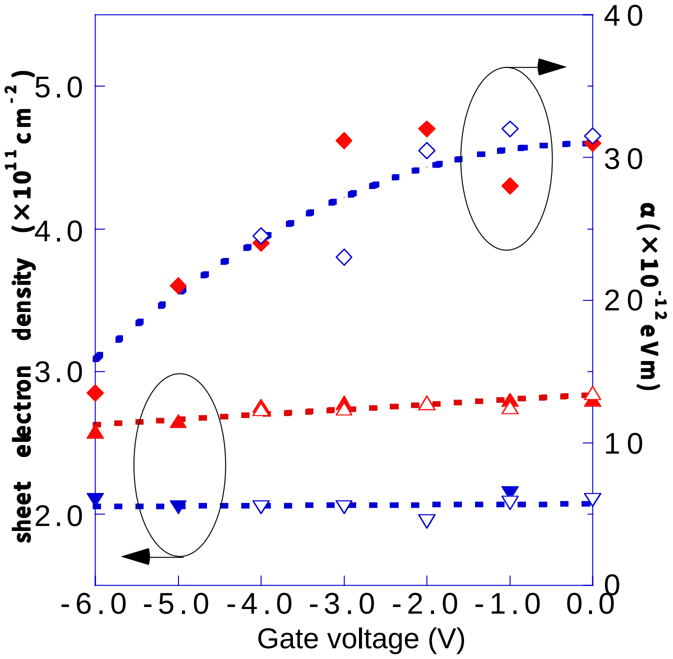

Fig. 1 Gate voltage dependencies of sheet electron densities, n_s^+ and n_s^-, of splitted bands and α_{zero} in front-gated Hall-bar samples. Triangle and diamond marks show spin-orbit interaction parameter, α_{zero}, and sheet electron densities, respectively. Close or open marks suggest direction of long side of the Hall-bar samples, directed <-110> and <110>, respectively.

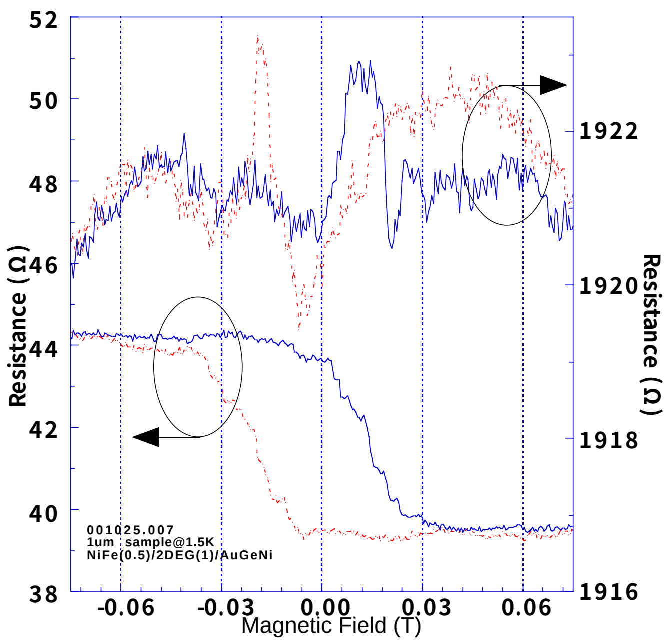

Fig.2 Magnetoresistance measurements in non-local geometry. The solid and dashed lines correspond to a sweep of magnetic field upward and downward.

Left axis : in non-local geometry. Right axis : source-drain resistance.