Spin-Polarized Transport in Rashba Quantum Point Contacts

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To realize the spin-FET [1] operation based on Rashba spin presession, the dimension of the device is an important problem, since the net presession angle depends on the electron path length between the source and drain electrodes, i.e., the direction of electron velocity in the device plane. The (ballistic ?) narrow wire or 1-dimensional structure thus becomes indispensable to restrict the velocity direction in the real spin-FET devices. Moreover, the mesoscopic physics expected in low dimensional Rashba effect structure made in narrow-gap heterijunctions is a new and attractive topic of semiconductor transport. We therefore recently fabricated and analyzed quantum point contacts (QPCs) in high In-content InGaAs / InAlAs heterojunctions, which have a strong spin-orbit interaction as well as a very high electron mobility at low temperatures [2].

Figure 1 is a schematic cross-sectional view of the QPC device which has a wire structure with finger metal side-gates, since the top surface Schottky-gate structure is difficult to make due to the narrow gap nature of our heterojunction. Figure 2 displays two-terminal conductances as functions of side-gate voltage with an applied vertical magnetic field as a parameter. Note here that those traces indicate the conductance steps in unit of not ($2e^2/h$) but (e^2/h). Such a result was confirmed reproducibly in other samples with different dimensions. This result is surprising, since it might suggest spin-polarized transport in the QPC region, if the other origins such as an electron-electron interaction etc are excluded. In fact, we observed ($2e^2/h$) conductance steps in the thick insulator split-gate QPC made for comparison. The main difference between the two-kind QPCs is rather the adiabaticity of the structure. That is, the dimension change is two-, one- and two-dimensional in the split-gate device, while it is almost quasi one-, one- and quasi-one dimensional in wire side-gate. In this sense, most possible explanation for this phenomenon might be that recently proposed by Governale et al [3]. They gave a picture of band mixing between the lower and upper 1-dimensional subbands under the strong Rashba interaction, which give rise to the subband mixing and hence spin-alignment in $\pm \boldsymbol{k}$ directions. Threshold width of the wire less than which this effect occurs is represented by $\boldsymbol{w_{th}} \sim \pi/\boldsymbol{k_{so}}$, where $\boldsymbol{k_{so}}$ corresponds to the Rashba spin splitting Δ_{so} and becomes ~100 nm in our case. Such a wire-like adiabatic constriction is likely realized in our wire QPC by the side-gates. It is however not clear that this $\boldsymbol{w_{th}}$ is indeed realized or not in our side-gate QPCs .In addition, conductance traces taken for increasing parallel magnetic fields did not show such an improvement of the clearness of the (e^2/h) steps suggesting non-Zeeman origin of the (e^2/h) steps in Fig. 2. Those results supports the spin-polarized transport in our QPCs due to the subband mixing.

References

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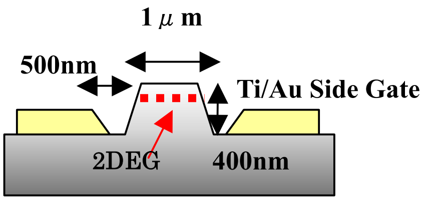

Fig.1 Schematic cross-sectional view of the wire QPC with finger side-gates

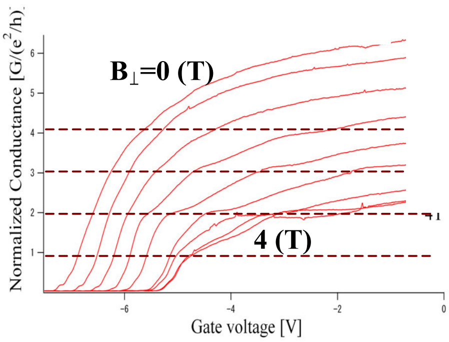

Fig.2 Conductance vs gate voltage with B⊥ as a parameter (0.5 T step)