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Detection of inter-subband carrier rearrangement by using a magnetic focusing technique

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An InGaAs-based quantum point contact (QPC) generates a spin-polarized current without magnetic fields and magnetic materials [1, 2], which is one of the promising candidates for future spintronic devices. In order to realize spin functional devices, evaluation of the current spin polarization in QPC structures is indispensable, which also reveals detailed mechanism of spin polarization in the QPC. Magnetic focusing in a semiconductor two-dimensional electron gas (2DEG) is attracting to evaluate the spin polarization in a mesoscopic transport measurement [3]. However, the magnetic focusing in an InGaAs 2DEG is still challenging in comparison with a GaAs 2DEG system due to limited gate control. In this work, we demonstrate the magnetic focusing in the InGaAs 2DEG by using two narrow constrictions (NCs), and investigate the effect of in-plane magnetic field on the InGaAs 2DEG.

A wafer consists of an $In_{0.7}Ga_{0.3}As$ / $In_{0.53}Ga_{0.47}As$ structure and was processed into two parallel NCs with a Hall bar structure by means of electron beam lithography and reactive ion etching, as shown in an inset of Fig. 1. Both the NCs and the Hall bar are covered with an AlO gate insulator and a Cr / Au top gate electrode. By applying the positive top gate bias V_g, not only the first subband but also the second subband are occupied by the induced electrons. Under multi-subband occupations, by applying an in-plane magnetic field, we investigate the population and depopulation of subband densities due to the diamagnetic effect and the field dependent effective mass. All the measurements are performed at $T = 1.7$ K.

Figure 1 shows the in-plane magnetic field dependence of focusing peaks with single subband occupation. The focusing peaks do not change under the applied in-plane magnetic fields. On the other hand, when both first and second subbands are occupied, the two peaks are shifted to opposite magnetic field strength with the in-plane magnetic fields, as shown in Fig. 2. These two peaks correspond to the first and second subands. The magnetic field at peak positions (B_p) have the relation $B_p = (\hbar/er_c)\sqrt{2\pi N_s}$, where $\hbar$ is a Planck's constant, e is an electron charge, r_c is a cyclotron radius of a device, and N_s is the carrier density for the subbands. In addition, this peak shift is reproduced by calculated B_p, which takes into account both the diamagnetic effect and field dependent effective mass. These results suggest that we observe inter-subband carrier rearrangement as the focusing peak shift.

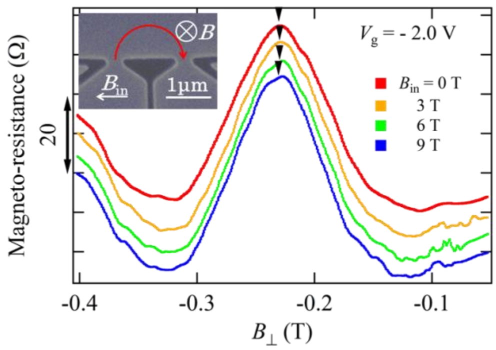

Figure 1 : In-plane magnetic field dependence of a focusing peak with single subband occupation. Inset shows an SEM image of the NC device.

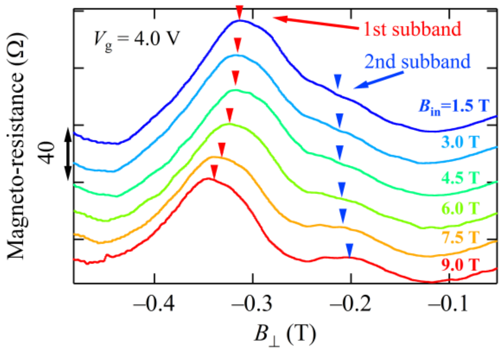

Figure 2 : In-plane magnetic field dependence of focusing peaks with first and second subbands occupation.

References

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