Spin Polarization of Electrons in Lateral Periodic Potential Around Filling Factor ν=3

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Abstract

We have investigated the spin polarization of electrons in a Be-δ-doped single heterojunction modulated by a field-induced lateral potential by a circularly polarized magneto-photoluminescence spectroscopy. We observe minimum in the polarization of the lowest state at the filling factor ν~3 at a bias voltage V_B =0 V. The minimum becomes less pronounced with increase in the lateral periodic potential, which is related with unstabilization of the Skyrmion excitation.

Introduction

A circular polarization dependent photoluminescence (PL) spectroscopy is a powerful tool for direct detection of the spin polarization of electrons in the two-dimensional electron systems (2DES). This method has been successfully applied for the investigations of the Skyrmionic excitations at ν=1 [1]. In constrast to the case of ν=1 [2], there have been arguments for the observation of the Skyrmionic excitations at odd integer $\nu \geq 3$ [3]. Kerridge et al. interpreted the depolarization of the lowest state of the 2DES to be due to the formation of Skyrmions [4]. In this paper, we report the dependence of this depolarization on the magnitude of a lateral periodic potential.

Results and discussions

The lateral periodic potential is tuned by applying a bias voltage (V_B) between a back gate and a surface gate of square mesh of a period of 250-400 nm prepared by the electron beam lithography on a Be-δ-doped single heterojunction [5]. A Be-δ-doped layer is located 25 nm from the heterointerface with a nominal doping density of 2×10^{10} cm^{-2}. The electron density was estimated to be 3.6×10^{11} cm^{-2} from an optical Shubnikov-de Haas measurement without applying V_B. PL spectra were obtained by illuminating the samples at 800 nm at the excitation power density of about 10 mW/cm^2 at 1.8 K. The results are shown for the σ^+ excitation. No significant difference is observed between the excitation polarizations.

The magnetic field dependencies of the degree of circular polarization of the PL from the four lowest Landau-levels (LLN, N=0, 1, 2, 3) at V_B = 0 V in the low magnetic field regime are shown in Fig. 1. The polarization of the PL from the partly occupied Landau-levels shows maxima at odd filling factors (ν=5, 7) due to the enhancement of the spin splitting in agreement with the literature [1].

Figure 2 shows the magnetic field dependencies of the degree of circular polarization of the PL from the lowest state at V_B = 0 V, -0.3 V, -0.5 V. The minimum at around ν~3 for LL0 was ascribed to be due to the Skyrmion formation [5]. No polarization maximum is observed in Fig. 2 at ν=3 in the partly occupied second Landau-level at V_B=0 V, probably due to the saturation of the degree of the polarization. The position of the minimum at ν=3.17 (4.7 T) in the lowest state is not shifted between V_B = 0 V and -0.3 V indicating that the local electron density at the lateral position mainly contributing to the PL is not decreased by the negative bias voltage. This minimum disappears at V_B = -0.5 V, which can be interpreted that the Skyrmion stability depends on the magnitude of the lateral confinement potential. Measurements are also performed for samples with a surface gate structure of

square mesh of a period of 250 nm, and qualitatively similar but stronger V_B dependencies are observed. Lateral potential modulation energy is estimated to be about 0.5 meV at V_B = -0.5 V [5]. The application of the lateral potential is considered to change the exchange energy and hence the spin configuratoin of the electrons. The abrupt change of the magnetic field dependencies between V_B = -0.3 and -0.5 V may support the picture of the Skyrmion formation at □=3.

In summary, the spin polarization of electrons in a field-induced lateral potential is investigated by a circularly polarized magneto-photoluminescence spectroscopy. The observed minimum in the polarization at □~3 becomes less pronounced with increase in the magnitude of the lateral periodic potential, which is related to unstabilization of the Skyrmion excitation.

References

[1] I.V. Kukushkin, K.v. Klitzing, and K. Eberl, Phys. Rev. B **55** 10607 (1997); I.V. Kukushkin, K.v. Klitzing, and K. Eberl, Phys. Rev. B **60** 2554 (1999).

[2] S.L. Sondhi, A. Karlhede, and S.A. Kivelson, Phys. Rev. B **47** 16419 (1993).

[3] X. -G. Wu and S.L. Sondhi, Phys. Rev. B **51** 14725 (1995); A. Schmelle et al., Phys. Rev. Lett. **75** 4290 (1995); N.R. Cooper Phys. Rev. B **55** R1934 (1997).

[4] G.C. Kerridge et al, Phys. Rev. B **60** R5141 (1999).

[5] S. Nomura and Y. Aoyagi, Surface Science (in press).

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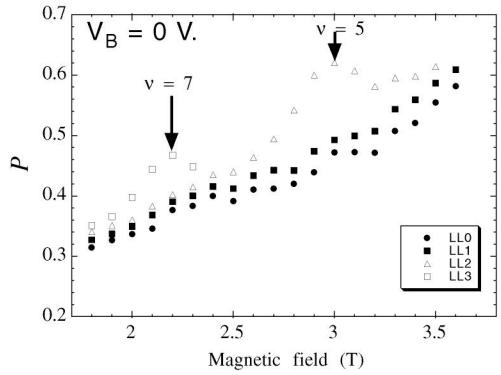

Fig. 1 Magnetic field dependent polarization of the PL from LL0 (closed circles), LL1 (closed boxes), LL2 (open triangles), and LL3 (open boxes) at V_B = 0 V in the low magnetic field regime.

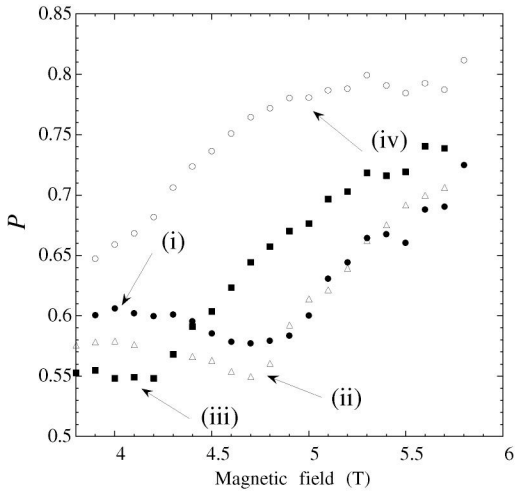

Fig. 2 Magnetic field dependent polarization of the PL from the lowest state at V_B = (i) 0 V (closed circles), (ii) -0.3 V (open triangles), (iii) -0.5 V (closed boxes), and from (iv) LL1 at V_B = 0 V(open circles) .