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Growth and Magneto-transport Characterization of Double-doped InGaAs/InAlAs Heterostructures with High Indium Compositions

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Abstract. We investigated double-doped InGaAs/InAlAs heterostructures with high indium compositions. The heterostructures were grown by molecular beam epitaxy on GaAs(001) with metamorphic step-graded buffer layers. The magneto-transport characterization was performed by using Hall-bar devices. We observed non-monotonic magneto-resistance oscillations, which indicate a single two-dimensional electron gas (2DEG) with multiple-subband occupation or a 2DEG bilayer. We also observed weak-antilocalization in all samples, which is an evidence of spin-orbit coupling.

Keywords: InGaAs/InAlAs, double-doped heterostructure, multiple subband occupation, two-dimensional electron gas (2DEG) bilayer, spin-orbit coupling
PACS: 73.61.Ey, 71.70.Ej

INTRODUCTION

Indium-containing III-V heterostructures have been paid much attention, because these have strong Rashba spin-orbit coupling (SOC), which is important for non-magnetic-semiconductor spintronic device applications such as Datta-Das spin field effect transistors [1]. Recently, a novel spintronic device structure based on double-doped wide quantum wells (QWs) with Rashba SOC has been proposed by Ekenberg and Gvozdic [2], and this can act as a spin-switch device by the interaction of electron spins in two-dimensional electron gas (2DEG) bilayer. However, to our knowledge, there is no experimental report on such double-doped wide QWs with Rashba SOC. Our group has demonstrated strong Rashba SOC in normal- and inverted-modulation-doped InGaAs/InAlAs heterostructures with high indium compositions [3, 4], and these are applicable to fabricate double-doped wide QWs. In this paper, we report the first trial of growth and magneto-transport characterization of double-doped InGaAs/InAlAs heterostructures with high indium compositions.

EXPERIMENTS

By a conventional molecular beam epitaxy on GaAs (001) surfaces with metamorphic InAlAs step-graded buffer layers, we grew double-doped InGaAs/InAlAs heterostructures which have two regions of Si delta-doping in surface and substrate sides against the InGaAs QW. The concentration of Si delta-doping was fixed to nominally 6×10^{11} cm^{-2}, and the spacer thickness was fixed to 20 nm. The indium composition, x_{In}, for both InGaAs QW and InAlAs barrier was fixed to nominally 0.75. The depth from the surface to the InGaAs QW was also fixed to 70 nm. The QW thicknesses varied from 40 to 120 nm.

Figure 1(a) shows an X-ray diffraction (XRD) result of the sample of t_{QW} = 120 nm. A major peak and its shoulder correspond to InAlAs barrier (x_{In} = 0.74) and InGaAs QW (x_{In} = 0.77), respectively. These indium compositions are close to the design (nominal) values, however, the InGaAs QW can be slightly compressively-strained. Figure 2(b) shows a surface morphology of the sample of t_{QW} = 120 nm by atomic force microscopy (AFM). We observed typical cross-hatch morphology. The XRD and AFM results are almost independent of t_{QW}.

For the magneto-transport characterization, we fabricated Hall-bar devices by a conventional photolithography. We performed the magneto-transport characterization at 1.5 K by using lock-in amplifiers and a superconducting magnet. From the Hall-effect, the sheet electron concentrations n_s and the electron mobilities μ_e are estimated to be 8.4-9.4$\times10^{11}$

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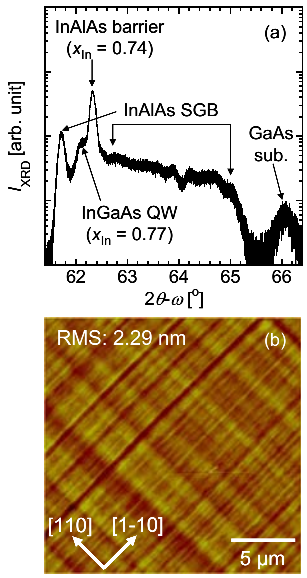

FIGURE 1. (a) XRD and (b) AFM results (t_{QW}=120 nm).

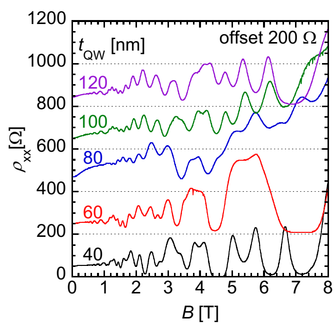

FIGURE 2. MR curves of the samples.

cm^{-2} and 1.1-1.5×10^5 cm^2/Vs, respectively. The QW thickness does not affect n_s so much, whereas the minimum μ_e is observed in the middle, the 80-nm-thick QW case. Figure 2 shows magneto-resistivity (MR) curves of the Hall-bar devices. All MR curves do not seem monotonic oscillations, which indicate a single 2DEG with multiple-subband occupation or a 2DEG bilayer. Figure 3 shows characteristic field B_c obtained from the fast Fourier transform (FFT) of the MR curves. The inset shows an FFT result. From the order of n_s, B_{c3} cannot correspond to the specific states. Since B_{c0} is almost same as the difference between B_{c2} and B_{c1}, B_{c0} also cannot correspond to the specific states. Therefore, B_{c2} and B_{c1} can correspond to the ground state (or the substrate-side state) and the first state (or the surface-side state), respectively. This assignment is consistent with the fact that (B_{c2} - B_{c1}) or B_{c0} in thick QW case (100 or 120 nm) is smaller than that in thin QW case (40 or 60 nm). Thus, degenerated

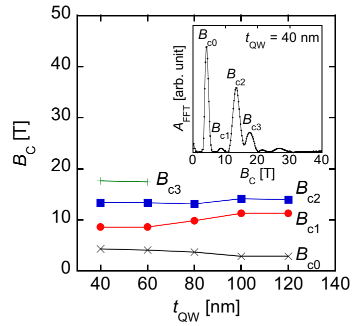

FIGURE 3. Characteristic fields from FFT results.

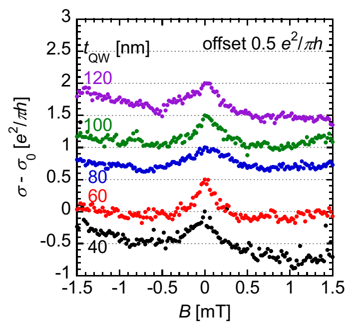

FIGURE 4. Magneto-conductivity curves of the samples.

2DEG bilayers can be obtained in the thick QW cases, whereas the multiple-subband occupation with tight quantum confinement can take place in the thin QW cases. In the case of 80-nm-thick QW, the system can be the 2DEG bilayer while weak interaction may take place simultaneously, resulting in the minimum μ_e. Although it is difficult to find any evidence of SOC from Fig. 2 and 3 (oscillation beatings, FFT double-peaks, etc.), all samples show the conductivity peak at B = 0 originating from weak anti-localization (WAL), which is an evidence of SOC, as shown in Fig. 4.

SUMMARY

We formed the metamorphic-grown double-doped InGaAs/InAlAs heterostructures, and observed non-monotonic MR oscillations and WAL behavior in them. The results indicate a multiple-subband 2DEG or a 2DEG bilayer with SOC.

REFERENCES

1. S. Datta and B. Das, Appl. Phys. Lett. **56**, 665 (1990).
2. U. Ekenberg and D. M. Gvozdic, Phys. Rev. B **78**, 205317 (2008).
3. Y. Sato et al., J. Appl. Phys. **89**, 8017 (2001).
4. H. K. Choi et al., Physica E **40**, 2823 (2008).

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