Quantum-well Thickness Dependence on the Spin-orbit Interaction Parameter in Inserted InAs Heterostructure

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1. Introduction

Spin-orbit interaction (SOI) is very important to control spin precession in semiconductor channel without external magnetic field. The Rashba effect induced by SOI enables to imagine the spin field effect transistor in which the resistance modulation is achieved by precession of spins moving in a channel. The SOI parameter, α is determined by both macroscopic electric field and the electron probability density. In addition, the quantum-well (QW) thickness, which determines the confinement of the wave function in the heterostructure, also has an effect on the overall strength of the SOI parameter. From this point of view, we investigated the QW thickness dependence on the SOI parameter in InAs two dimensional electron gas (2DEG) structure.

2. Experiment details

Inverted type InAs high electron mobility transistor (HEMT) structure was used to calculate the SOI parameter. Fig. 1 shows the cross section of inverted type InAs HEMT structure we prepared for our experiment. The InAs QW is placed between the $In_{0.52}Al_{0.48}As/In_{0.53}Ga_{0.47}As$ double cladding layers and the carrier supply layer is located below the InAs QW. Inverted 2DEG structures with QW thickness ranging from 0 - 7 nm were grown on a InP(001) substrate using the molecular beam epitaxy (MBE). The samples were processed into $64 \times 80\ \mu m^2$ Hall bars to obtain the Shubnikov-de Hass (S-dH) oscillation curve. Fig. 2 shows the S-dH oscillation curves with various QW thickness. While perpendicular magnetic fields were applied to QW plane, we observed the beat patterns in the measurement of the S-dH curve at 1.8 K. From these results, we calculated the SOI parameter and sheet carrier concentration respectively without an external electric field.

3. Results and discussion

Fig. 3 shows the SOI parameter (α) and the total sheet carrier concentration (nS) including spin up and down charge as a function of InAs QW thickness. In a our experiment, We found that SOI parameter of no InAs QW is about 5.7×10^{-12} eV·m and dramatically increases to 8.7×10^{-12} eV·m at 1 nm InAs QW. The SOI parameter linearly decayed with increasing the QW thickness over 1nm. On the other hand, the total sheet carrier density is less dependent on the InAs QW thickness. The InAs QW thickness yielding a substantial change of SOI parameter (α) indicates that it should be optimized in order to have easy manipulation of spin precession inside 2DEG.

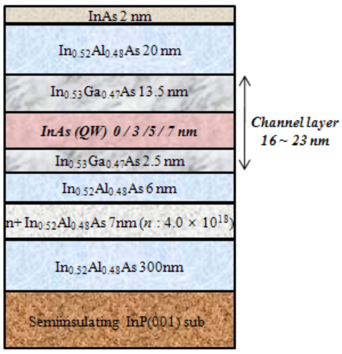

Fig. 1. Cross section of an InAs-inserted InGaAs/InAlAs heterostructure.

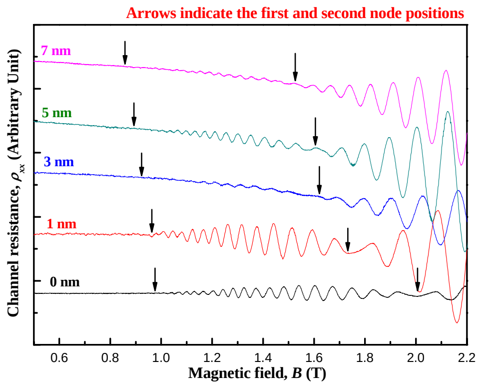

Fig. 2. Shubnikov-de Hass (S-dH) oscillations at T = 1.8 K. InAs QW thickness ranging from 0-7 nm.

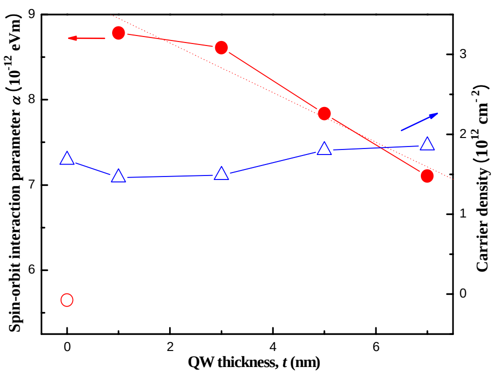

Fig. 3. InAs QW thickness dependence of the spin-orbit interaction parameter (α) and the total sheet carrier concentration (n_S) including spin up and down;

4. References

[1] Jae Hyun Kwon *et al.* , Appl. Phys. Lett. 90, p. 112505.

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