Influence of the Magnetic Field on Rashba Effect in an $In_{0.53}Ga_{0.47}As$ Qantum Well Structure

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1. Introduction

Recently, the efforts to realize the spin field effect transistor (Spin-FET) that has great potential for next generation devices have been researched. In order to operate a spin-FET, two essential factors, i.e., spin-orbit interaction (α) and the spin injection from a ferromagnet to a semiconductor are should be considered. The Rashba effect is that the effective magnetic field (B_R) is induced in the y-direction when moving electrons (k_x) inside the channel under a perpendicular electric field (E_z) induced either internally of externally. An external magnetic field is commonly used for determining the magnetization of the ferromagnets.

In our research, we measured the spin-orbit interaction (α) and effective mass (m^*) by the Shunikov-de Hass oscillation (SdH) measurement and investigated the effect of the magnetic field on Rashba effect in an In53Ga47As quantum well structure.

2. Experimental

In this experiment, an inverted heterostructure with an $In_{0.53}Ga_{0.47}As$ channel grown by molecular beam epitaxy on a semi-insulated InP(100) substrate is used. The channel layer is confined by the $In_{0.52}Al_{0.48}As$ cladding layers and the carrier supply layer locates below the In0.53Ga0.47As quantum well layer. The thickness of the channel layer is 16 nm. A 64 μm width of hall-bar pattern was defined by using photolithography and ion milling and no current flow in the outside area of the patterned channel was ensured.

3. Results and Discussion

Figure 1 shows the results of Shunikov-de Hass oscillation (SdH) measurement at T = 1.8 K. The bias current is 15 μA and a perpendicular external magnetic field is applied. We obtain the spin-orbit interaction and the carrier concentration is $\alpha = 7.5 \times 10^{-12}$ eVm and $n_s = 2.0 \times 10^{-12}$ cm^{-3}, respectively.

Temperature dependence of SdH oscillation is shown in Fig. 2 and we found that the amplitude of SdH oscillation decreases with increasing temperature. From the data in Fig. 2, the effective mass (m^*) can be calculated as shown in Fig. 3[1]. The circles correspond to the results from calculation using the difference of the amplitude and the line is plotted for fitting linear in Fig. 3, which shows that the effective mass is proportional to an external magnet field. However, the spin-orbit interaction parameter (α) is inversely proportion to the effective mass. The effective magnetic field is expressed as $B_R = \alpha k_F/\mu_B g$, where k_F is the Fermi wave number, μ_B is the Bohr magneton, and g is the electron g-fector [2]. The external magnet field (B_T) considerably affect the effective magnetic field (B_R) that have a range from B_R = 1.43 T to B_R = 0.86 T for 4 T < B_T < 7 T.

4. Conclusion

The Rashba field and the effective mass are obtained by the Shunikov-de Hass oscillation (SdH) measurement in an $In_{53}Ga_{47}As$ quantum well structure and we also found that these factors are inversely proportion to each other.

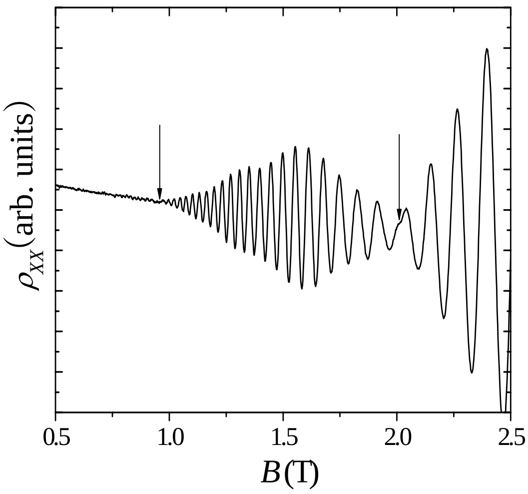

Fig. 1. The results of Shunikov-de Hass oscillation (SdH) measurement at 1.8 K.

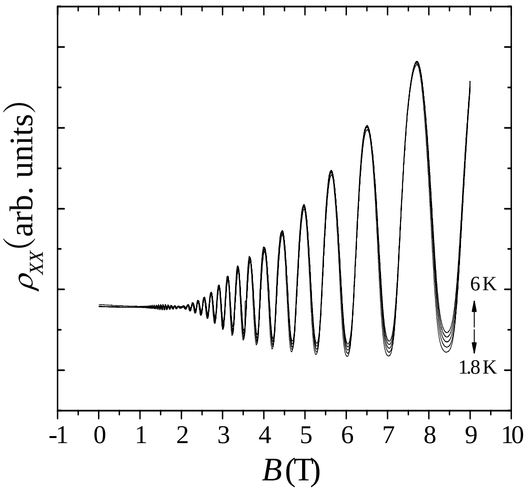

Fig. 2. Temperature dependence of SdH oscillation at 1.8 K, 3 K, 4 K, 5 K, and 6 K.

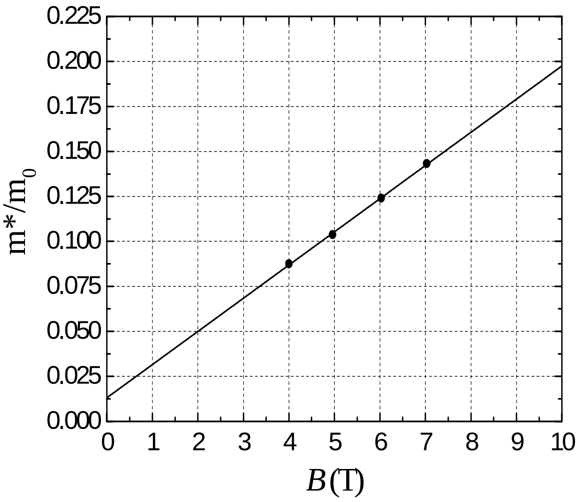

Fig. 3 Effective mass vs. external magnetic field.

5. References

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