Detection of Gate-controlled Rashba Effect Using Potentiometric Measurement

Youn Ho Park[1,2]*, Hyun Cheol Jang[1], Hyun Cheol Koo[1], Hyung-jun Kim[1], Joonyeon Chang[1], Heon-Jin Choi[2], Suk-Hee Han[1] and Hijung Kim[1]

[1]Spin device Research Center, Korea Institute of Science and Technology, Seoul 136-791,Korea

[2]Department of Materials science and Engineering, Yonsei University, Seoul 120-749, Korea

1. Introduction

A Two-dimensional electron gas structure has been considered as a good channel for developing spin devices, because it has the large Rashba field which plays a key role in spin modulation. The spin-orbit interaction parameter (α), induced by the Rashba effect ($B_{R,y}$), is produced when moving electrons (k_x) inside a channel under a perpendicular electric field (E_z) and can be controlled by the gate electrode[1].

In our research, we measured Gate dependence of Rashba effect using potentiometric measurement in an InAs quantum well structure. The potentiometric measurement is simpler for calculating the amount of Rashba field than other methods such as the Shunikov-de Hass oscillation (SdH) measurement and Weak Anti-localization analysis (WAL)[2, 3].

2. Experimental

We utilized an inverted heterostructure with a 2 nm InAs channel grown by molecular beam epitaxy on a semi-insulated InP(100) substrate. The In0.52Al0.48As/In0.53Ga0.47As double cladding layers wrap the channel layer. The carrier concentration and mobility are ns = 2.01×10^{-12} cm^{-3} and μ = 55 000 $cm^2V^{-1}s^{-1}$ at T = 1.8 K, respectively. A 8 μm width channel was defined by using photo-lithography and ion milling and no current flow in the outside area of the patterned channel was ensured. The permalloy electrode (FM) was deposited for potentiometric measurement. The thickness and lateral size of FM was 80 nm and 0.5 μm × 32 μm, respectively. The 100 nm thickness of SiO_x was used as an insulator for a top gate electrode.

3. Results and Discussion

Figure 1 shows the potentiometric measurement geometry. The bias current is 0.1 mA, and the voltage is measured between the FM and end of channel with applying an external magnetic field due to define magnetization direction of FM. As shown in Fig 2(a), using the alignment of between FM and channel we measured the spin dependent chemical potential shifts (potentiometric signals) which is proportional to the spin-orbit interaction.

We also can manipulate the potentiometric signals (△R) using the applied gate voltages as shown in Fig 2 at T = 1.8 K. In the results the signals increase with the negative gate voltages, which corresponds to the gate dependence of the spin-orbit interaction in an inverted InAs quantum well system[4].

4. Conclusion

We detected spin dependent potential shifts using potentiometric measurement and also the gate dependence was measured in an InAs quantum well structure T = 1.8 K. From the results, the potentiometric signal decreases with increasing gate voltage, which is well-matched with the gate dependence of spin-orbit interaction in an inverted quantum well system.

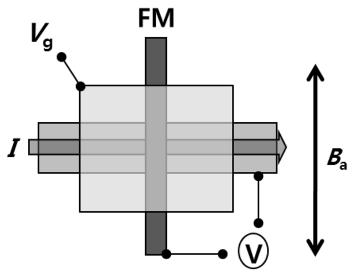

Fig. 1. potentiometric measurement geometry.

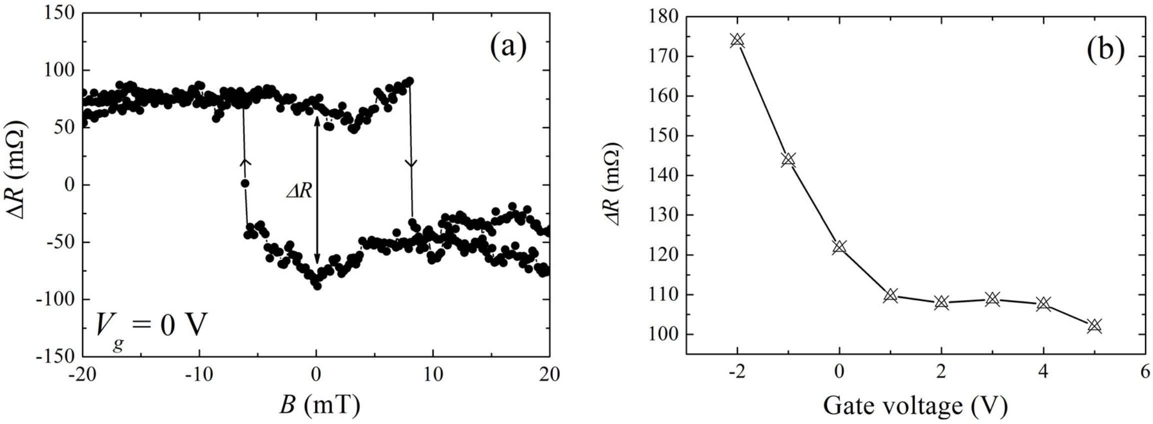

Fig. 2. (a) Results of potentiometric measurement and (b) Gate dependence of potentiometric signals at T = 1.8 K.

References

[1] H. C. Koo, J. H. Kwon, J. Eom, J. Chang, S. H. Han, and M. Johnson, Science **325**, 1515 (2009)

[2] Y. H. Park, H. C. Koo, K. H. Kim, H. Kim, J. Chang, S. H. Han, and H. Kim, IEEE Trans. Mag. **46**, 1562 (2010).

[3] H. C. Jang, Y. H. Park, H. C. Koo, H. Kim, J. Chang, and H Kim, J. Appl. Phys. **109**. 07C313 (2011)

[4] K. Kim, H. Kim, H. C. Koo, J. Chang, and S. Han, Appl. Phys. Lett. **97**. 012504 (2010)