Electric Field Control of Spin Orientation in a Semiconductor Channel

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1. Introduction

The spin field effect transistor (spin-FET) [1] is the still one of the most attractive schemes because spin precession can be actively utilized to logic applications. Recently, remarkable progress on electrical detection of spin precession has been accomplished by using an external magnetic field in materials with weak spin-orbit interactions. On the other hand, a strong spin-orbit interaction gives a marvelous phenomenon that spin precession can be manipulated not by an external magnetic field but by a gate electric field, which has a great advantage for device applications. Here, we demonstrate gate control of spin precession in an InAs quantum well with ferromagnetic spin injector and detector. The gate electric field modulates the spin-orbit interaction and modifies the amount of spin precession.

2. Experimental

We have fabricated mesoscopic lateral spin valve devices that simultaneously exhibit electrical spin injection and gate modulation[2]. The device consists of two ferromagnetic electrodes (FMs) on top of an InAs high-electron-mobility transistor (HEMT) channel and a gate electrode. The InAs HEMT was grown by molecular beam epitaxy on a semi-insulating InP(100) substrate. The quantum well, which functions as a two-dimensional electron gas (2DEG) channel, is present at a depth of 35.5 nm from the top surface. The carrier density and mobility of the 2DEG are n = 2.1-2.8×10^{12} cm^{-2} and μ = 50,000-60,000 $cm^2V^{-1}s^{-1}$ at 1.8 K. The representative sizes of two ferromagnetic electrodes are 0.4 mm × 80 mm and 0.5 mm × 40 mm.

3. Results and Discussion

Figures 1(a) and (b) show the schematics of spin devices and detected signals. In the top geometry of Fig. 1(a), the orientation of injected spins, along the *y*-axis, is parallel with the Rashba field. There is no spin precession and no modulation of voltage recorded by the detector. The magnetization orientations of injector and detector are along +*x*-direction (the bottom geometry of Fig. 1(a)) and the injected spin orientation is perpendicular to the Rashba field. The spin precession varies as a function of gate voltage and an oscillation of detected voltage, as a function of VG, is observed as shown in Fig. 1(b). The range of gate voltage is sufficiently large that more than one full cycle of voltage oscillation is recorded. If one of the injector or detector is replaced by non-ferromagnet, no signal is detected. Data from a conventional lateral spin valve measurement are shown in Fig. 1(c). When a external magnetic field is swept along the *y*-axis, the magnetization alignment of FMs changes between parallel and anti-parallel configurations, and the detector voltage V is high or low, respectively.

4. Conclusion

Gate-controlled spin orientation in a semiconductor channel was observed for the lateral spin-valve geometry. The results in this experiment confirm that electrical field can control the magnetic property of the travelling electrons in a semiconductor. In order to implement efficient spin transport, the spin transistor channel requires large spin-orbit interaction parameter as well as very short channel which can be realized by the current nano-fabrication technology.

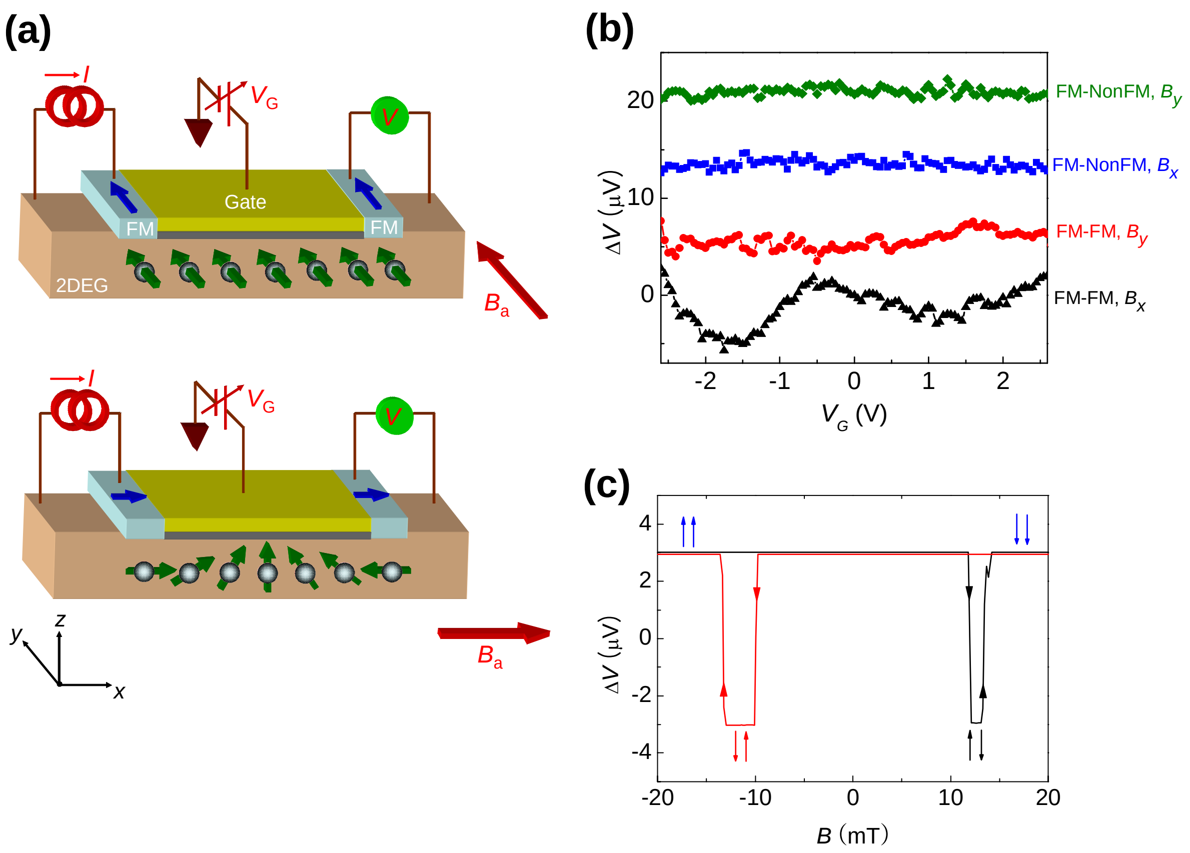

Fig. 1 Gate control of spin precession. (a) Device geometry (b) Gate control signal. (c) Conventional nonlocal signal.

5. References

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