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Spin transport in an InAs based two-dimensional electron gas (2DEG) nano-channel

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I. Introduction

Spin field effect transistor (spin-FET) is a major concern in the field of spin electronics because of its high performance and low power consumption. Spin injection and detection in the semiconductor systems are of great importance to realize spin-FET. In previous works on a two-dimensional electron gas (2DEG) structure, the channel length, i.e., the distance between two ferromagnetic electrodes (FM) and the channel width were micron-sized scale.[1-4] In this study, a sub-micron scaled spin device of FM1/InAs 2DEG[5-6]/FM2 heterostructure was fabricated to enhance spin transport properties with the help of electron-beam lithography (EBL).

II. Experiments

The high mobility InAs single quantum well structure is grown with molecular beam epitaxy on GaAs substrate and the vertical structure is similar to those reported by others.[2,7] A 30 Å top InAs layer acts as a capping layer preventing the GaAlSb layer from oxidizing and reducing leakage current. A 150 Å InAs 2DEG is formed between the two GaAlSb layers and the 200 Å upper GaAlSb layer acts also as a low transmission layer enhancing spin injection efficiency. [2, 8-10] The InAs mesa is defined with photolithography technology and Ar ion milling. The outside of mesa is etched out about 500 Å down to the lower GaAlSb to confine the current path and is passivated with TaO_x to prevent the direct contact between the ferromagnetic electrodes and the sidewall of 2DEG that can produce unwanted signals. In an effort to make a narrow spin transport channel, a trench pattern is made on the mesa pattern with EBL. After doing EBL, the trench pattern is Ar ion milled by 50 nm, passivated with TaO_x, and lifted-off. Co0.9Fe0.1 ferromagnetic electrodes, with different aspect ratios are used as spin injector and detector. The thickness of ferromagnetic electrode is 60 nm and the dimensions of FM1 and FM2 are 21 μm×0.4 μm and 17 μm×2.4 μm, respectively. All measurements were performed by both a typical DC measurement and an AC lock-in technique. Temperatures and the external magnetic field were controlled by PPMS of Quantum Design.

III. Results and discussion

In the measurement, the bias current of 50 μA is applied from the upper side of the InAs mesa to the lower one, therefore the spin polarized electron is injected from FM1 to the 2DEG mesa.(non-local method) The voltage difference resulted from the accumulated spins is detected between one side of FM1 (V+) and the opposite side of FM2 (V-). When FM1 provides spin-up electrons to the 2DEG mesa, then the up-spin chemical potential of InAs single quantum well is raised and the down-spin chemical potential is depleted.[2] When M1 and M2 are parallel (anti-parallel) each other, a relatively high (low) chemical potential is sensed. The measured $R_{non\text{-}local}$ of the sample at 77 K is presented in Fig.1.

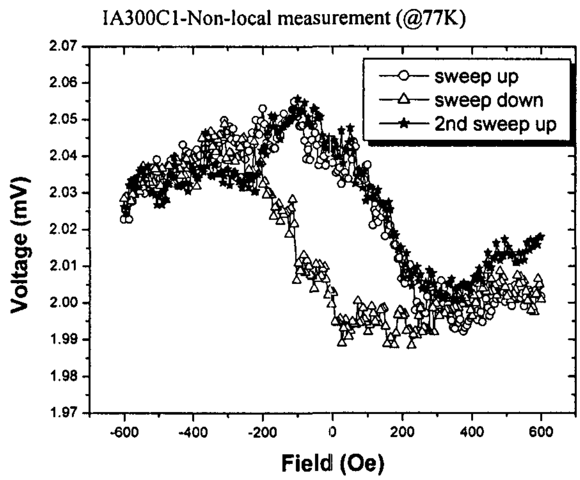

Fig. 1 Resistance curves for a non-local geometry at 77K.

The peak-to-dip voltage difference $\Delta\mu(=\mu_{M1\uparrow M2\uparrow} - \mu_{M1\uparrow M2\downarrow})$ in Fig.1 is about 0.057 mV, i.e., $\Delta V = I \times \Delta R$ = 50 μA × 1.144 Ω=0.057 mV. The 1.144 Ω is at least three times higher than the previously reported data.[2] (0.3 Ω) This improvement is believed to come from the short gap between FM1 and FM2 because the number of injected spin polarized electrons decays exponentially, $Ns \propto e^{-L/s,x}$ Note that s,x is a spin coherence length and is a product of spin velocity and relaxation time. The non-local voltage modulation shown in Fig. 1 is a strong evidence of electrical spin injection and detection. Moreover, the effect of narrower channel width can be another reason of the enhanced signal.

VI. Conclusion

In summary, we have investigated spin transport at a FM_1/2DEG/FM_2 junction. In the non-local method, ΔV= 0.057 mV (ΔR= ΔV/I= 1.144 Ω) between InAs mesa and the ferromagnetic electrode was obtained at 77 K. These values are several times higher than previous result. The main reason is the nano-sized channel length, which increases the possibility for spin-polarized electrons to arrive at spin detector and therefore enhances the overall spin signal.

V. References

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