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Detection of spin accumulation induced by spin Hall effect

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Electrical spin detection has drawn a great interest in the field of ferromagnet-semiconductor hybrid system. The Hall voltage measurement is a common method to detect potential difference between the opposite sides of a thin conductor or semiconductor. Spin Hall effect in semiconductor is optically detected [1], but no electrical voltage was detected in pure spin Hall effect due to the same number of accumulated spin-up and -down electrons [2, 3]. In this research, the stray field induced by ferromagnetic pattern is used to align spins in flowing electrons. The spin polarized electrons will experience asymmetric scattering due to the strong spin-orbit coupling in InAs-based semiconductors, and yield to a transverse voltage even in absence of external field.

The top view of spin Hall device geometry is shown in Fig. 1(a). The two-dimensional electron gas channel (2DEG) is defined by ion milling followed by oxide deposition and the channel width is 1 μm. The high mobility heterostructure consists of InAlAs/InGaAs/InAs/InGaAs/InAlAs and the thickness of InAs channel is 2 nm thick. Ferromagnetic electrode (NiFe) with thickness of 70 nm was deposited by e-beam evaporation and the lateral dimension is 2 μm by 40 μm in order to utilize shape anisotropy. Superconductor (Pb) is also deposited for shielding the direct fringe field in the Hall bar region. The distance between the ferromagnet edge and the detection point is only 1 μm which is smaller than spin diffusion length of InAs channel. In order to block the direct current flowing through the ferromagnet and superconductor, AlOx is inserted before metal deposition.

The spin alignment direction of the electrons at the gap between permalloy and Pb patterns is selected by magnetization direction of permalloy. i. e. the magnetization in the +x and -x direction produces stray field in the -z and +z direction, respectively. From the calculation the maximum stray field to the z-direction for this geometry is 4 kOe. The voltage probe detects the unbalanced number of electrons and the sign of Hall voltage depends on the magnetization direction of ferromagnet.

Similar to in-field experiment, the sign of V-I curve slope depends on the magnetization direction. Due to the hysteretic nature of permalloy pattern the magnetization direction follows the previous in-field status. At remanence, the normal Hall effect can be eliminated but the detective voltage is only 10-30% of in-field experiment result. At remanent state overall magnetization direction is same as saturation state but the multi-domain exists at the ends of ferromagnetic electrode. The closure domain at edge causes serious stray field reduction to the z-direction.

In summary, we observed spin Hall effect in InAs 2DEG channel using stray-field-induced Zeeman energy splitting. The origin of this spin Hall effect is spin dependent deflection and the

results shows the spin transport and the electrical spin detection in a semiconductor channel.

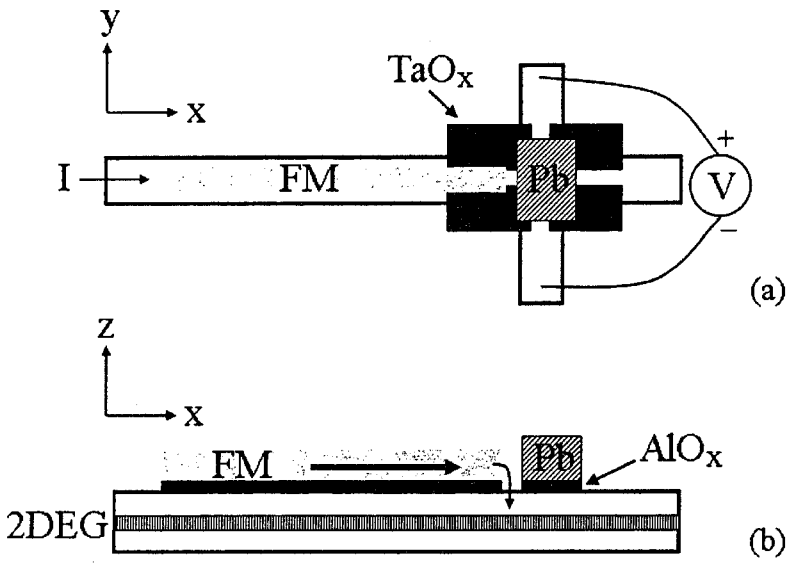

Fig. 1 Spin Hall device geometry. (a)Top view. (b)Cross sectional view.

References

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