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Electrical Detection of the Spin Hall Wffect in an InAs Quantum Well

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Importance of the spin-orbit coupling has been noted in spin transport studies on a variety of materials from a metal to a semiconductor. The spin-orbit coupling gives rise to a novel phenomenon known as the spin Hall effect in a paramagnetic material even without external magnetic field. Due to the spin-orbit coupling spins accumulate at the edge of the conducting channel, anda spin voltage arises. However, pure spin voltage without unbalanced charge accumulation is not detected by normal nonmagnetic Hall probes. One needs to employ a spin sensitive Hall probe made of ferromagnetic materials. Another smart way to electrically detect the spin Hall effect is to use a spin-polarized current. If electrons flowing in a conducting channel are spin polarized, the trajectory of moving electrons leans toward one-side so that an unbalanced charge accumulation arises.

In this experiment, we made a spin polarized current by Zeeman splitting in a two-dimensional electron under local fringe field which is created by a ferromagnetic film. Figure 1 shows the scanning electron micrpgraph of a spin Hall effect device. The device consisted of a ferromagnetic film and a Hall-bar-shaped two-dimensional electron gas which was made of InAs high electron mobility transistor. The ferromagnetic film is $Ni_{81}Fe_{19}$ with dimension of 2×40 μm^2 and thickness of 70 nm. The small bright rectangle in Fig. 1 represents a superconducting Pb film which preventsthe fringe field from penetrating through the Hall bar. Therefore, the ordinary Hall effect due to external magnetic field can be prohibited. For our device the spin Hall voltage was observed and the temperature dependence of the spin Hall resistance has been shown in Fig. 2. The estimated spin Hall sheet conductance of InAs was $9.4\times10^{-4}\ \Omega^{-1}$, which is measured electrically for the first time. The magnitude of spin Hall sheet conductance suggests that the observed signal originates from the extrinsic spin Hall effect [1].

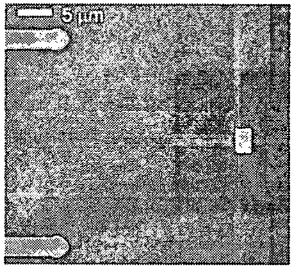

Fig. 1. Scanning electron micrograph of a spin Hall effect device.

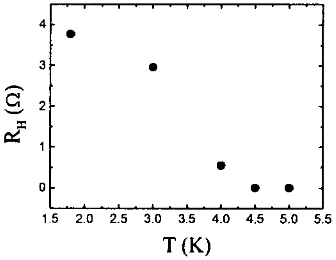

Fig. 2. Temperature dependence of transverse resistance of the spin Hall effect.

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Current-induced Domain Wall Motion Above a Threshold Current Density in the Adiabatic Limit

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Current-induced domain wall motion (CIDWM) is a way of manipulating domain walls (DWs) by a spin-polarized current [1]. It has been of considerable interest because of its potential use for the new type of high density storage device [2]. For the application, a sufficiently high DW velocity is strongly desired. The spin-transfer torque tiltsthe magnetization at the centre of DW out of the easy-plane in the adiabatic limit [3]. At a low current, the DW does not move steadily because the spin torque is balanced with the torque due to the demagnetization field. Above threshold, the shape of DW is significantly transformed with accompanying to anti-vortex injections [4]. During the steady DW motion, the anti-vortex is periodically injected to relax too high demagnetization energy. Since it is caused by the competition against the demagnetization energy, there should be a close relationship between the anti-vortex formation and the aspect ratio of nanostrip (=W/t, where W is the width and t is the thickness of nanostrip).

Here we performed micromagnetic simulation to study the velocity of a transverse wall (TW) with varying the aspect ratio. We used the Landau-Lifshitz-Gilbert equation with taking into account the adiabatic spin torque. The DW velocity is oscillatory at the initial stage [5], and decays with time. It starts increasing when the anti-vortex is formed at a side of nanostrip. At the peak of the velocity, the chirality of TW is opposite to the initial TW. The time-dependent variation of TW velocity is a perfect sinusoidal function when the nanostrip is thick enough (a small aspect ratio, 40×18nm^2 in Fig. 1 (a)). However, it is deviated from the perfect sinusoidal function as the aspect ratio increases (Fig. 2 (b), (c)). It is caused by significantly distorted anti-vortex due to too high demagnetization field. We will describe more detail at the presentation.

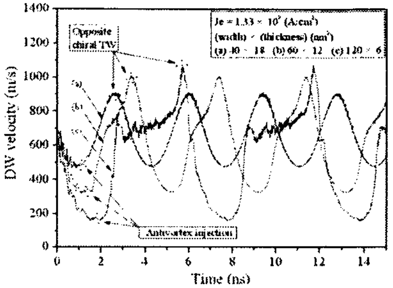

Fig. 1. Domain wall velocity as a function of the aspect ratio.

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