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Nonlocal spin valve measurement in multi Py electrodes on Au Channel

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Effective spin injection to nonmagnetic material(NM) gives rise to spin accumulation at anti-parallel magnetic configuration of two ferromagnetic electrodes(FM 's), which can be detected in the nonlocal spin valve(NLSV) measurement.[1~3] NLSV signal is associated with the distance between spin injector and detector, and the resistivity of nonmagnetic channel. Two types of distance exist in the currently spacing : one is the center to center distance and the other is edge to edge distance between two FMs. Usually center to center distance is widely available to calculate ΔR in the potential drop. It is meaningful to review which distance is more effective in estimating ΔR in NLSV measurement.

In addition, NLSV signal is largely dependent on the resistivity of NM channel. The resistivity of NM film is subjected to change from sample to sample depending on the deposition conditions so that some fluctuation of the resistivity may lead inconsistent NLSV signal at every samples. Therefore, it is necessary to keep the resistivity as constant as possible. Multi FM electrodes on single channel are preferable in order to minimize the variation of the resistivity.

An intervening FM electrode in multi FM devices was reported to significantly suppress the spin accumulation owing to spin current absorption into a connected additional FM[2]. Spin flip resistance in the additional FM is an important measure to judge whether the suppression happens or not. On the other hand, there is a contradictory report that the effect was negligible in the Py/Ag/Py devices.[3] There is still controversy on the effect of intervening FM in spin valve devices. This is an important issue to be addressed for measurement and evaluation of spin transport properties in high accuracy.

In this work, we fabricated Py/Au/Py spin valve devices with multi Py electrodes and measured series of nonlocal signal in various distances of Pys with or without an intervening Py electrode aiming at clarifying the uncertainty. For NLSV measurement, distinguished dips on sweep up and down can be found in every combinations of multi FMs. We have compared data for samples taken with intervening FM and without FM.

The device was patterned by the multilevel electron beam lithography and lift-off process. 60 nm thick Au film was deposited by sputtering to form 200 nm wide Au conducting channel on an oxidized Si substrate. Four Py ($Ni_{81}Fe_{19}$) electrodes with a different aspect ratio being separated by a center to center distance of 200 ~ 900 nm were fabricated on a pre-patterned Au channel. Junction area on Au transport channels was carefully cleaned by rf plasma in the 900 mm Torr oxygen environment prior to Py deposition in order to have good Ohmic contact. The measurements are performed by the standard ac lock-in-techniques with an excitation current 1mA at 15 K.

Samples with four Py electrodes connecting Au channel make possible to measure various distances of injector and detector by using different combination of injector and detector under constant Au resistivity.

Fig.1 shows the scanning electron microscope image of a fabricated device sample and geometry of the NLSV measurement method. There are four FM' s with different widths which can be denoted as FM1(0.58um), FM2(0.28um), FM3(0.28um) and FM4(0.28um). Center to center distance between FM1 and FM2, FM2 and FM3 is 0.53um and 0.34um respectively. But, both edge to edge distance range between FM1 to FM2 and FM2 to FM3 is the same as 110nm.

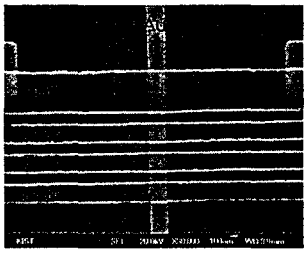

Figure 1. SEM image of the fabricated multi Py electrode spin valve device on Au channel

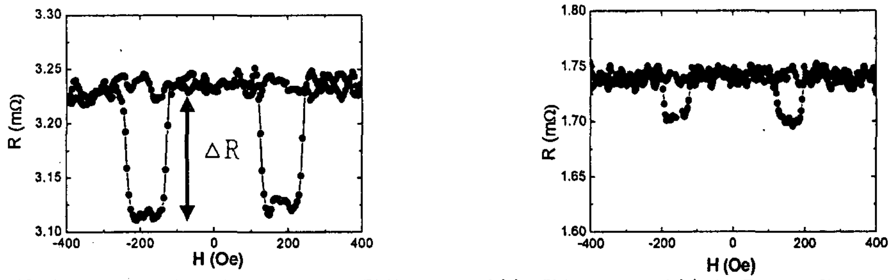

Figure 2. Nonlocal spin valve signal between FM1 and FM2(a), FM1 and FM3(b) in Fig. 1. The center to center distance between Py electrodes is 0.53 um (a) and 0.92 um(b)

We measured the NLSV signals in two different Center to center distances with the same edge to edge distance. (△R1=FM1 and FM2, △R2=FM2 and FM3)

The typical magnitude of NLSV spin injection signal of △R1 and △R2 is measured to 110 uΩ and 175 uΩ, *respectively. The difference in the magnitude of the signal may be due to the fact that the* center to center distance between FM2 and FM3 is shorter than that of FM1 and FM2. NLSV effect appears strong dependence of the center to center distance rather than edge to edge distance which is predicted by the theory.

NLSV signal was also measured at different distance using FM1~2 and FM1~3 of which distance is 0.54um and 0.92um respectively(Fig 2). Distinguished dips on sweep up and down can be found in both although △R of FM1~3 (30 uΩ) is even smaller than that of FM1~2 of 110 uΩ △R of FM1~3 is due to long spin diffusion path. For comparison, NLSV signal was also obtained in the device without any intervening Py electrode(FM2) at the same distance between FM1 and FM3 (0.92um). The obtained spin signal is 28uΩ which is almost same to that of intervening electrode . These results clearly show that intervening FM electrode dose not suppresses the spin accumulation. Comparison of our results with previous works and the controversy in multi FM devices will be discussed.

In conclusion, it is reasonable to use center to center distance when we predict △R in NLSV. Since intervening Py electrodes in multi FM devices dose not affect NLSV signal, simultaneous fabrication of multi Py electrodes with different separations on a spin channel is more favorable to evaluate consistent spin accumulation, spin diffusion length and injection polarization by fixing Au channel resistivity.

References

[1] J. Ku, J. Chang, H. Kim and J. Eom, Appl. Phys, Lett. 88, 172510 (2006)
[2] T. Kimura *et al.* Appl. Phys, Lett. 85, 3795 (2004)
[3] R. Godfrey, M. Johnson, Phys. Rev. Lett. 96, 136601 (2006)