Investigation of anisotropy of spin relaxation in Si-based lateral spin valve

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Si has good spin coherence due to its weak spin-orbit interaction and good compatibility with large scale integration technologies. It is essential to understand spin relaxation mechanism in Si for further progress of the Si spin devices. It has been reported that the dominant spin relaxation mechanism in Si was the Elliott-Yafet type spin scattering [1]. Other contributions in spin relaxation, such as spin scattering due to spin-orbit coupling, has not been so far fully investigated in previous studies. This spin scattering has an anisotropy depending on directions of spin component which are the in-plane and out-of-plane of the channel, due to the spin-orbit field [2]. In this study, we investigated anisotropy of the spin lifetime in Si-based lateral spin valve.

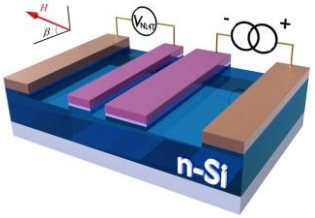

Fig. 1. Schematic image of lateral spin valve and experimental setup.

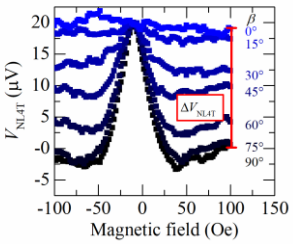

Fig. 2. Hanle curves with oblique magnetic fields in various angles

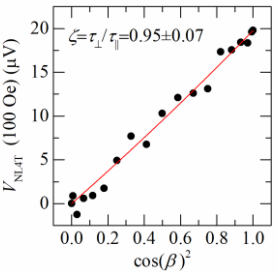

Fig. 3. V_{NL4T} (H = 100 Oe) of the Hanle curves versus $\cos^2(\beta)$

Non-degenerate Si based lateral spin valve device, which consists of two ferromagnetic contacts and two nonmagnetic contacts on Si channel, was exploited for spin transport (Fig. 1). Out-of-plane magnetic field induced spin precession with only in-plane spin relaxation. Meanwhile, both in-plane and out-of-plane spin relaxations occurred by oblique magnetic field, as shown in Fig. 1 [2]. The spin precession by oblique magnetic field, i.e. the oblique Hanle effect, was measured with the various angles between in-plane and out-of-plane directions (β).

Figure 2 shows β dependence of the Hanle curves. The magnitudes of the Hanle curves (ΔV_{NL4T}) were increased with increasing the angle, indicating dephasing of spin coherence. Figure 3 shows $\cos^2(\beta)$ dependence of V_{NL4T} (H = 100 Oe). For the isotropic case, V_{NL4T} (H = 100 Oe) versus $\cos^2(\beta)$ results in a straight line. The angle dependence of the magnitude of the oblique Hanle was fitted by the 1-dimensional model calculated from the Bloch equation [2]. It revealed that the anisotropy factor ζ, the ratio between the spin lifetimes for out-of-plane and in-plane spin components was estimated to be 0.95 ± 0.07. More detailed discussion will be given in the presentation.

[1] R. J. Elliott, Phys. Rev. 96, 266 (1954).

[2] B. Raes *et al.*, Nat. Commun. **7**, 11444 (2016).