Saturation of spin drift velocity in Si spin MOSFET under high electric field

○(M1)Soobeom Lee[1], Naoto Yamsashita[1], Yuichiro Ando[1], Shinji Miwa[2], Yoshishige Suzuki[2], Hayato Koike[3] and Masashi Shiraishi[1]

1. Department of Electronic Science and Engineering, Kyoto University, Kyoto 615-8510, Japan.

2. Graduate School of Engineering, Osaka University, Toyonaka 560-8531, Japan.

3. Technology HQ, TDK Corporation, Ichikawa 272-8558, Japan.

E-mail: lee.soobeom.32r@st.kyoto-u.ac.jp

Silicon (Si) is a promising candidate for spintronics and the information technology. Indeed, a long spin relaxation time is expected in this material because Si has lattice inversion symmetry and a weak spin orbit interaction. A successful room temperature operation of the spin metal-oxide semiconductor field-effect transistor (MOSFET) in Si has been demonstrated [1]. In addition, the magnitude of spin signal can be enhanced using spin drift effect [1–3]. However, spin transport under a high electric field has not been fully investigated, which can provide a significant material to discuss bias voltage dependence of the Si spin devices. In this study, we investigated the electric field dependence of spin drift velocity in non-degenerated Si lateral spin valves (LSVs).

As shown in Fig 1 (a), the Si-based LSV consisted of a P-doped nondegenerate n-type Si channel equipped with two ferromagnetic (FM) and two nonmagnetic electrodes. Spin polarized electric current was injected into the Si channel from the left FM electrode, accelerated by the electric field and extracted into the right FM electrode. When an out-of-plane magnetic field (B_z) was applied, spin precession occurred, i.e. the Hanle effect was induced and spin transport properties were estimated from the fitting of the Hanle effect.

It is known that charge drift velocity in Si is saturated due to optical phonon scattering under a high electric field (typically several kV/cm) [4]. In this study, spin drift velocity (v) was saturated above 10^4 V/cm, whereas spin relaxation time (τ_{sf}) and spin polarization (P) were decreased (see fig 1(b)). The electric field dependence of the spin drift velocity and the spin polarization are consistent with those in previous studies [4,5], and the decrease of the spin lifetime as a function of the electric field is attributable to the optical phonon scattering.

Fig1. (a)

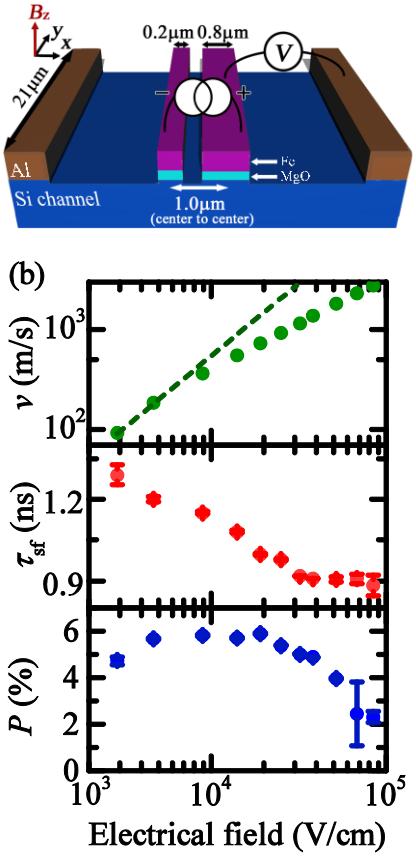

Fig 1 (a) A schematic image of Si-based LSV. (b) Electric field dependence of drift velocity (green), spin relaxation time (red) and spin polarization (blue), which were estimated from the Hanle effect measurements.

[1] T. Tahara, M. Shiraishi et. al., Appl. Phys. Express **8**, 113004 (2015).
[2] T. Tahara, M. Shiraishi et. al., Phys. Rev. B **93**, 214406 (2016).
[3] M. Kameno, M. Shiraishi et. al., Appl. Phys. Lett. **104**, 92409 (2014).
[4] C. Jacoboni et. al., Solid. State. Electron. **20**, 77 (1977).
[5] M. Shiraishi et. al., Phys. Rev. B **83**, 241204(R) (2011).

© 2017年 応用物理学会