Enhancement of spin signals by thermal annealing in silicon-based lateral spin-valves

Kyoto Univ. [1], TDK Corp. [2], Osaka Univ.[3]
○(D)Naoto Yamashita[1], S. Lee[1], R. Ohshima[1], E. Shigematsu[1], H. Koike[2],
Y. Suzuki[3], S. Miwa[3], M. Goto[3], Y. Ando[1], and M. Shiraishi[1]
E-mail: yamashita.naoto.64r@st.kyoto-u.ac.jp

Recently, several spintronic devices based on silicon (Si) have been demonstrated at room temperature[1-3]. For the practical use of these devices, in addition to the enhancement of spin polarization in Si, investigation of thermal endurance is necessary because thermal annealing has a variety of possible effects on spintronic devices. There has not been reported about endurance to post-fabrication annealing of the spintronic devices based on nondegenerate Si. Here, we studied the effects of thermal annealing on nondegenerate Si-based lateral spin-valve devices.

Our lateral spin-valve devices consist of nondegenerate Si (N_d = 2×10^{18} cm^{-3}, 80 nm) and ferromagnetic electrodes made of n^+-Si (N_d = 5×10^{19} cm^{-3}, 20 nm)/MgO(0.8 nm)/CoFe(0.6 nm)/Fe(12.4 nm). The schematic image of the sample is shown in Fig. 1. Thermal annealing was carried out after the fabrication of the devices to compare the spin signals before and after the annealing. The temperature was set to 300℃ for 1 hour in a vacuum during the annealing.

The nonlocal four-terminal method was employed to measure the spin signals. The spin signals before and after the annealing are shown in Fig. 2(a). Clear rectangular signals (ΔV_{nl}) depending on the sweep direction of the magnetic field (B_y) were observed even after the annealing. It was clarified that the device has endurance for the post-fabrication annealing up to 300℃.

Here, the magnitude of the spin signals increased more than two-fold after the annealing. The notable increase of the spin signals was confirmed in several devices. The channel length (L) dependence of the spin signals, which was shown in Fig. 2(b), was measured to investigate the spin diffusion length and the spin polarization. The analysis insists the increase in ΔV_{nl} is attributed to the enhancement of the spin polarization. Thermal annealing is suggested as a simple method to enhance the spin polarization in nondegenerate Si-based spintronic devices.

[Reference]

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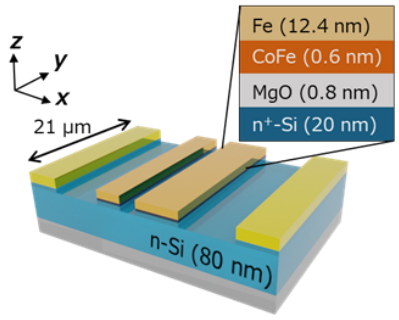

Fig. 1. Schematic image of a sample. The lateral spin-valve structure based on n-Si was employed.

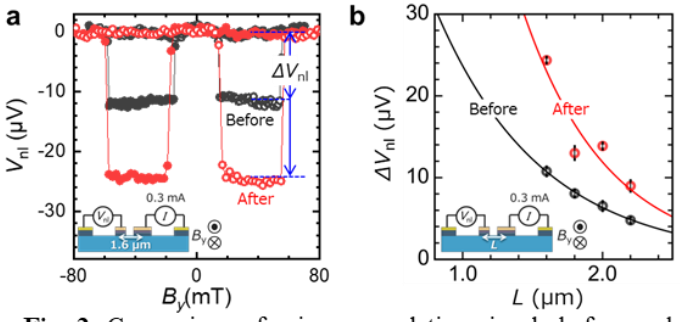

Fig. 2. Comparison of spin accumulation signals before and after thermal annealing at 300 ℃. **(a)** Measured spin accumulation signals. **(b)** The channel length (L) dependence of the spin accumulation signals.