Detection of hole spin transport in Ge using lateral spin-valve structures

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Detection of hole spin transport in p-Ge is quite challenging because the strong influence of the spin-orbit interaction in the valence band leads to very short hole spin relaxation times ($\tau_s < \sim 1$ ps at 300 K). [1] Although electrical detection of spin-polarized holes in p-Ge has been reported by a three-terminal method, [2] the reliability of the measurement is still an open question. [3] Here we present hole spin-transport measurements in a p-Ge(111) layer using a Cu-based nonlocal lateral spin valve (LSV) with a p-Ge(111)/Fe$_3$Si heterointerface. [4, 5]

By performing reliable nonlocal measurements for the fabricated Fe$_3$Si/Cu/p-Ge(111)/Fe$_3$Si LSV (LSV with p-Ge), we observed a hysteretic nonlocal spin signal ($\Delta R_S$) at various temperatures. Figure 1 shows the temperature dependence of the $\Delta R_S$ for the LSV with p-Ge (red closed circles), together with that for a conventional Fe$_3$Si/Cu/Fe$_3$Si LSV (LSV without p-Ge) (black open squares). As measurement temperature increases, the magnitude of $\Delta R_S$ rapidly decreases at ~60 K and disappears at ~150 K. For the LSV without p-Ge, on the other hand, $\Delta R_S$ has ordinary temperature dependence. Using a general one-dimensional spin diffusion model, [6] we can understand that the temperature dependence of the $\Delta R_S$ for the LSV with p-Ge originates from spin accumulation and relaxation in p-Ge and the $\tau_s$ at 10 K is roughly estimated to be ~41 ps. We infer that the relatively long $\tau_s$ is attributed to the suppression of spin relaxation at the L point in the valence band.

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Fig. 1 Temperature dependence of $\Delta R_S$ for an LSV with p-Ge (red closed circles), together with that for an LSV without p-Ge (black open squares).