Spin-dependent transport through n-Ge in vertical spin-valve devices

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Recently, we observed spin-dependent transport through p-Ge in vertically stacked CoFe/p-Ge/Fe_3Si spin-valve devices at room temperature (RT) [1]. However, the observed local spin signals (ΔR_S) were relatively small (~5 mΩ) [1] because of a very short spin relaxation time (τ_S ~ 0.4 ps at RT), leading to a small spin diffusion length. On the other hand, we have so far clarified the spin relaxation time of n-Ge (τ_S ~ 0.2 ns at RT) [2], much longer than that of p-Ge. Here we try to fabricate CoFe/n-Ge/Fe_3Si tilayer structures and to observe spin-dependent transport through the n-Ge layer in the vertically stacked devices.

By combining solid phase epitaxy (SPE) and molecular beam epitaxy (MBE) with Sb doping, we grew a 15 ~ 20-nm-thick Sb-doped Ge layer on Fe_3Si layer [3], followed by a 10-nm-thick CoFe layer. We confirmed streaky RHEED pattern for each process, indicating two-dimensional epitaxial growth (Fig. 1).

Using the CoFe/Sb-doped Ge/Fe_3Si structure, we fabricated vertical spin-valve devices with a junction size of ~ 0.66 μm^2, as shown in Fig. 2(a). Because symmetric and nonlinear current-voltage (I-V) curves were observed [Fig. 2(b)], we can judge that the tunneling conduction of electrons through the metal/n-Ge interfaces is achieved [3]. Figure 2(c) shows a representative magnetoresistance curve at RT with I_{dc} = 0.2 mA. A hysteretic feature depending on the magnetization states between parallel and anti-parallel can be observed. The value of ΔR_S is ~ 40 mΩ, which is one order of magnitude larger than that for p-Ge devices [1].

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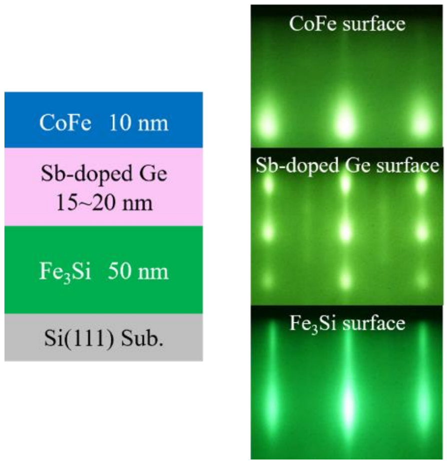

Fig.1: Surface RHEED observations of Fe_3Si, Sb-doped Ge and CoFe layers.

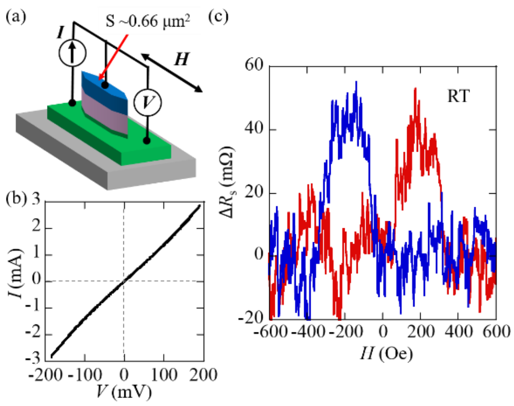

Fig. 2: (a) Schematic and (b) I-V curve and (c) magnetoresistance curve of a CoFe/Sb-doped Ge/Fe_3Si spin valve at RT.