Investigation of Electrical Spin Injection into GaAs Using $Co_2Fe_{0.4}Mn_{0.6}Si$ Heusler Alloy

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The spin-MOSFET is expected to show a high performance in integrated circuits [1]. Highly efficient spin injection into semiconductors from ferromagnet is important for the realization of spin-MOSFET. However, it is difficult to realize efficient spin injection due to the conduction mismatch problem [2]. In order to enhance the efficiency of spin injection, it was proposed to use a half-metal theoretically having a spin polarization of 100% [2]. In this study, we focused on $Co_2Fe_{0.4}Mn_{0.6}Si$ (CFMS) Heusler alloy and aimed to fabricate high quality thin films on GaAs substrates for the realization of high efficiency of spin injection into GaAs.

A structure of CFMS (30nm)/Ta (5nm) was deposited by magnetron sputtering on undoped GaAs (100) substrates. The annealing temperature (T_a) of CFMS layer was 200 - 600ºC. The films with same structure were also deposited on GaAs (undoped)/n-GaAs(100 μ m) substrates at T_a = 400ºC, which has the maximum saturation magnetization of CFMS films. For detecting spin injection signal, we performed 3-terminal Hanle measurement at 10 K.

Fig. 1 shows the annealing temperature dependence of the saturation magnetization of CFMS thin films deposited on the undoped GaAs substrate. The saturation magnetization increased with increasing annealing temperature, and the maximum M_S ~ 925 emu/cc was obtained at T_a = 400ºC. The obtained high M_s indicates high B2 ordering in the CFMS films. Fig. 2 shows the Hanle signal using n-GaAs substrate. The spin relaxation time calculated from the narrow Hanle signals is about 7 ns, which is comparable to theoretical value [3] and previous report [4]. The result indicates that the spin-injection into GaAs was successfully demonstrated using highly ordered CFMS films. This work was supported by Center for Science and Innovation in Spintronics, and Center for Spintronics Research Network, Tohoku University.

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[3] Pil Hun Song *et al.*, Phys. Rev. B **66**, 035207(2002). [4] P. A. Peterson *et al*., Phys. Rev. B **94**, 235309 (2016).

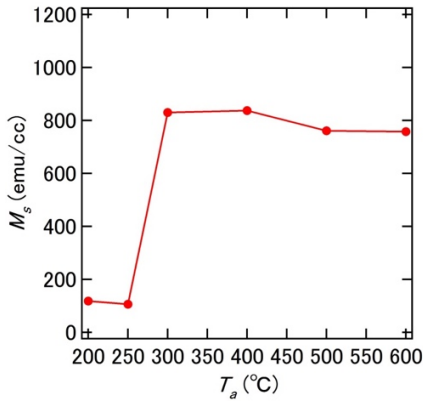

Fig. 1 T_a dependence of M_s in CFMS films

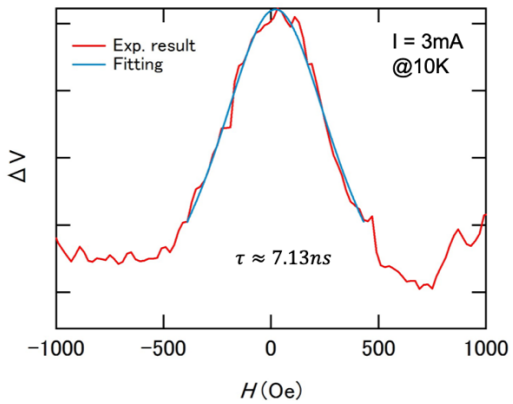

Fig. 2 Narrow Hanle signal in GaAs/CFMS device