Combinatorial optimization for high spin polarization in Heusler alloy composition-spread thin films by anisotropic magnetoresistance effect

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Half-metallic Co-based full-Heusler alloys have been promising candidates for spintronic applications such as tunnel magnetoresistance (TMR) and current-perpendicular-to-plane giant magnetoresistance (CPP-GMR) devices due to their high spin polarization and high Curie temperature [1]. It is shown both theoretically and experimentally that the spin polarization of Heusler alloys strongly depends on the alloy composition [2]. Thus, the optimization of atomic composition of Heusler alloys is crucial for obtaining high spin polarization. However, because of many fabrication steps for those devices, compositional optimization using TMR and CPP-GMR devices is a time-consuming process.

Recently, the measurement of anisotropic magnetoresistance (AMR) effect has been proposed as a facile way to evaluate the spin polarization of Heusler alloys [3]. The magnitude of negative AMR ratio showed a qualitative correlation with the magnitude of GMR for various Heusler alloys, which indicates that a large negative AMR ratio corresponds to a high spin polarization [3].

Combinatorial technique such as using composition-spread films has been widely used for high-throughput material screening. The composition-spread film is the film whose composition changes continuously within a single piece of substrate. By employing the AMR measurement on Heusler alloy composition-spread films, a high-throughput optimization for high spin polarization would be possible.

In this study, we performed a high-throughput compositional optimization method for high spin polarization in Co_2(Mn, Fe)Ge (CMFG) Heusler alloy by a combination of composition-spread films and AMR measurement [4]. From this method, we observed high spin polarization of over 80% at room temperature in polycrystalline $L2_1$-ordered CMFG Heusler alloy thin films on SiO_2/Si substrates. Two types of composition-spread films of $Co_2(Mn_{1-x}Fe_x)Ge$ and $(Co_2Mn_{0.5}Fe_{0.5})_{1-y}Ge_y$ were fabricated by combinatorial sputtering deposition, followed by post-annealing. The compositional dependence of AMR showed the largest negative AMR ratio of –0.13% for y = 0.25 in the $(Co_2Mn_{0.5}Fe_{0.5})_{1-y}Ge_y$ composition-spread film. By measuring spin accumulation signals of nonlocal spin-valve devices, the highest spin polarization of 82% was obtained in the region for y = 0.24. Thus, a clear qualitative correlation between the large negative AMR ratio and high spin polarization was confirmed. The combinatorial optimization method combining composition-spread films and AMR measurement proposed in this study was proved to be an efficient high-throughput strategy for the development of half-metallic Heusler alloys with high spin polarization.

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