# Mn-composition dependence of magnetoresistance ratio of $Co_2MnSi$-based giant magneto-resistance devices

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Co-based Heusler alloy thin films have been extensively studied as a promising ferromagnetic electrode material for spintronic devices, including magnetic tunnel junctions (MTJs)[1-4] and giant magnetoresistance (GMR) devices[5,6], and for spin injection into semiconductors.[7] We have shown that harmful defects in Heusler alloy thin films of $Co_2MnSi$ (CMS), $Co_2(Mn,Fe)Si$ (CMFS), and $Co_2MnGe$ can be suppressed by appropriately controlling the film composition, *i.e.*, $Co_{Mn}$ antisites detrimental to the half-metallicity can be suppressed by adding an excess Mn,[1] and have demonstrated high tunneling magnetoresistance (TMR) ratios of up to 1995% (354%) at 4.2 K (290 K) in CMS/MgO/CMS MTJs having Mn-rich CMS electrodes,[2] and up to 2611% (429%) at 4.2 K (290 K) in CMFS/MgO/CMFS MTJs having (Mn+Fe)-rich CMFS electrodes.[3] The purpose of the present study was to clarify the influence of off-stoichiometry for CMS films on the MR ratio of GMR devices. To do this, we fabricated current-perpendicular-to-plane (CPP)-GMR devices having CMS electrodes with various Mn compositions, α, and an Ag spacer, and investigated the influence of α on the magnetoresistance (MR) characteristics.

The fabricated GMR layer structures were as follows: (from the substrate side) MgO buffer (10 nm)/CoFe seed (10)/Ag buffer (100)/CoFe buffer (10)/CMS lower electrode (3)/CoFe (1.1)/Ag spacer (5)/CoFe (1.1)/CMS upper electrode (3)/CoFe (1.1)/IrMn (10)/Ru cap (5) with $Co_2Mn_\alpha Si_{0.82}$ electrodes, grown on MgO(001) substrates. The preparation procedure of CMS electrodes with various values of α was the same as for the CMS/MgO MTJs.[1-4] Just after the deposition of CMS upper electrodes, the layer structure was *in-situ* annealed at 550 °C. We fabricated GMR devices with the nominal junction sizes ranging from 70 × 120 nm$^2$ to 400 × 640 nm$^2$ by using EB lithography and Ar ion milling. The MR characteristics were measured using a dc four-probe method at room temperature.

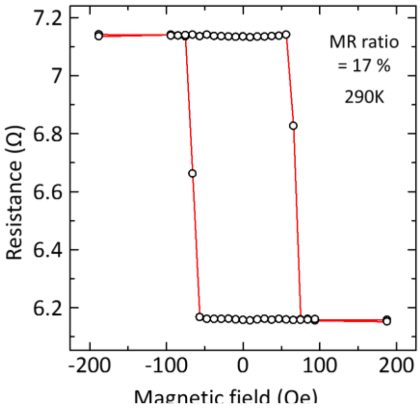


Fig. 1. A typical MR curve at 290 K for a CMS/CoFe (1.1 nm)/Ag/CoFe (1.1 nm)/CMS GMR device with Mn-rich α = 1.45 CMS electrodes. The nominal junction size was 70 × 120 nm$^2$.

Figure 1 shows a typical MR curve for a GMR device having $Co_2Mn_{1.45}Si_{0.82}$ electrodes. It showed clear MR characteristics with a MR ratio of approximately 17%. The values of $R_P{\cdot}A$ and $\Delta R{\cdot}A$ were 52 mΩ·μm$^2$ and 8.4 mΩ·μm$^2$, respectively, where $\Delta R = R_{AP} - R_P$, $R_{P(AP)}$ is the junction resistance for parallel (antiparallel) configuration, and $A$ is the nominal junction size. Figure 2 shows MR ratios as a function of Mn composition, α. The MR ratio increased with increasing α from 9% for Mn-deficient α = 0.62 to 17% for Mn-rich α = 1.45. This result suggests a continuous increase in the spin polarization with increasing α from a Mn-deficient to a Mn-rich composition. Thus, it is demonstrated that enhancing the half-metallicity of CMS by appropriate control of the film composition toward a Mn-rich one is also highly effective in CMS-based GMR devices as in the MTJs.

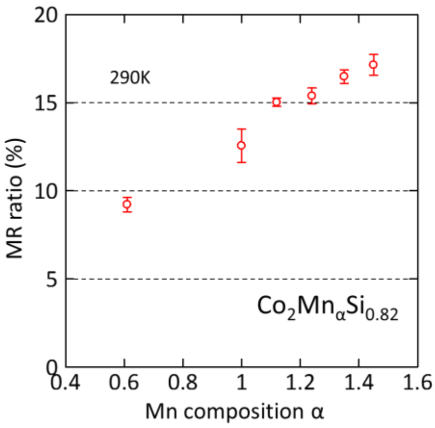


Fig. 2. MR ratios at 290K for CMS/CoFe (1.1 nm)/Ag/CoFe (1.1 nm)/CMS GMR devices as a function of the film composition α $Co_2Mn_\alpha Si_{0.82}$ electrodes.

## References

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