

# Influence of Ge composition in $\text{Co}_2\text{Fe}(\text{Ga},\text{Ge})$ films on magnetoresistance characteristics of $\text{Co}_2\text{Fe}(\text{Ga},\text{Ge})$ -based current-perpendicular-to-plane spin valves

<sup>o</sup>Tessei Tanimoto<sup>1</sup>, Masaki Inoue<sup>1</sup>, Yuki Chikaso<sup>1</sup>, Kazuumi Inubushi<sup>2</sup>,

Katsuyuki Nakada<sup>2</sup>, and Tetsuya Uemura<sup>1</sup>

<sup>1</sup> Grad. School of Information Science and Technology, Hokkaido University, Japan

<sup>2</sup> Technology & Intellectual Property HQ, TDK Corporation, Japan

E-mail: te\_tanimoto@eis.hokudai.ac.jp

## 1. Introduction

Current-perpendicular-to-plane (CPP) giant magnetoresistance (GMR) devices using Co-based Heusler alloys have attracted much interest as read sensors for next-generation hard disk drives.<sup>1-5</sup> We have demonstrated that the MR ratio at 290 K increased as the Mn composition of  $\text{Co}_2\text{MnSi}$  (CMS) in CMS-based CPP-GMR devices increased and have shown that Mn-rich CMS is highly effective in suppressing  $\text{Co}_{\text{Mn}}$  antisite, which is detrimental to the half-metallicity.<sup>4</sup> However, non-negligible diffusion of Mn atoms from Mn-rich CMS electrodes into an Ag spacer was also observed, which limits the MR ratios to relatively small values. On the other hand, relatively high MR ratios of more than 50% at room temperature was recently reported in CPP-GMR devices using  $\text{Co}_2\text{Fe}(\text{Ga},\text{Ge})$  (CFGG) electrodes with no Mn atoms,<sup>5</sup> however the influence of the film composition of CFGG on the MR characteristics has not been clear. The purpose of this study is to clarify the influence of Ge composition in CFGG electrodes on the MR characteristics of CFGG-based CPP-GMR devices.

## 2. Experimental Methods

We prepared two series of CFGG-based CPP-GMR devices without NiAl insertion layer at the CFGG/Ag interface (series-A) and with an ultrathin NiAl insertion layer at the lower and upper interface (series-B) both with various Ge composition  $\alpha$  in  $\text{Co}_2\text{Fe}_{1.03}\text{Ga}_{0.41}\text{Ge}_\alpha$  electrodes ranging from 0.56 to 1.06. The layer structures of the series-A CPP-GMR were as follows: (from the substrate side) MgO buffer (10 nm)/ $\text{Co}_{50}\text{Fe}_{50}$  (CoFe) seed (10)/Ag buffer (100)/CFGG lower electrode (10)/Ag spacer(5)/CFGG upper electrode (8)/Ru cap (5), grown on MgO(001) substrates. For series-B CPP-GMR ultrathin (0.21 nm) NiAl layers were inserted at both interfaces of the Ag spacer with the lower and upper CFGG electrodes, aiming to enhancing the MR ratio.<sup>5</sup> Just after the deposition of CFGG upper electrodes, the layer structure was *in-situ* annealed at 550°C. We fabricated CPP spin valves with the nominal junction sizes ranging from  $70 \times 120$  nm to  $400 \times 640$  nm by using EB lithography and Ar ion milling. The MR characteristics were measured using a dc four-probe method at 290 K.

## 3. Results and Discussion

Fig. 1(a) shows a typical MR curve at 290 K for a series-B CPP-GMR device with  $\alpha = 1.06$ . A clear MR curve with relatively high MR ratio of 55.6% was obtained. Fig. 1 (b) shows  $\alpha$  dependence of the MR ratio. The MR ratio increased as  $\alpha$  increased in both series-A and series-B devices. This result suggests that Ge-rich CFGG is effective in improving the half-metallic character of CFGG, possibly due to the suppression of Co antisite with the increase of Ge composition.

### References

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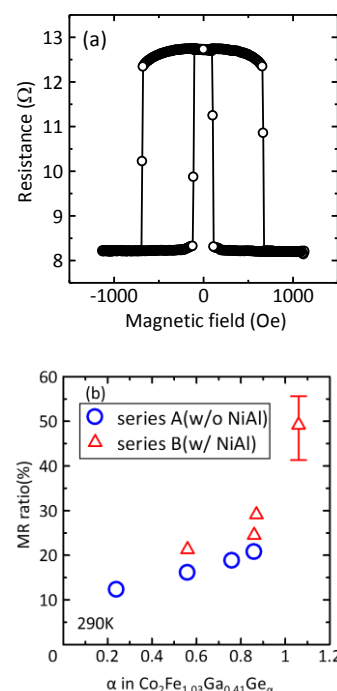


Fig. 1. (a) MR curve for a series-B CPP-GMR device with  $\alpha = 1.06$ . (b) MR ratio of CFGG-based CPP-GMR devices as a function of  $\alpha$ .