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Presentation Title

Spin-dependent transport in current-perpendicular-to-plane/current-in-plane devices with highly spin-polarized Heusler compounds

Abstract

Half-metallic ferromagnets (HMFs), which possess perfectly spin-polarized conduction electrons due to the semiconducting gap in either the up- or down-spin channel at the Fermi level, are attracting much interest in spintronics because they are expected to enhance and elicit various spin-dependent phenomena and improve the performance of applications. Recently, several Co-based full-Heusler compounds, a class of HMFs, such as Co_2MnSi (CMS), Co_2MnGe, and $Co_2FeAl_{0.5}Si_{0.5}$, have been applied as ferromagnetic electrodes in magnetic tunnel junctions and large MR ratios due to high spin-polarization have been reported at low temperature (LT) successfully[1,2]. However, MR ratio drastically decreases with temperature due to the thermal fluctuation of magnetic moments and/or the impurities and dislocations at the barrier/Heusler electrode interfaces. Thus, it is one of the most challenging works to realize high spin-polarization reflecting a half-metallcity not only at LT but also room temperature (RT) for future spintronics. The final goal of our research in this project is to realize nearly ideal half-metallicity at RT in the current-perpendicular-to-plane/current-in-plane type devices.

One of the most promising next application of half-metallic Heusler compounds is the electrode for CPP-GMR devices which have a structure of ferromagnetic electrode/nonmagnetic spacer/ferromagnetic electrode. Because the spin-dependent electron scatterings not only at the interface but also inside the bulk region can contribute to the MR effect. In this study, we have fabricated the CPP-GMR devices with the (001)-oriented fully-epitaxial CMS/Ag/CMS structures and successfully observed large MR ratio over 30% at RT as shown in Fig.1[3-5]. This MR ratio was one order of magnitude larger than that reported in the CPP-GMR devices with convention transition metals such as Fe or Co. We also analyzed the spin-asymmetry of electric resistivity at the interface and in the bulk region (represented by the coefficients γ and β, respectively) on the basis of the two-current model proposed by Valet and Fert. The result showed that the interface spin-asymmetry γ was quite large and predominantly contributes to observed large MR ratio.[4] We successfully clarified by the theoretical support from Prof. Shirai's group that the origin of large γ is the good Fermi surface

matching of majority spin electron band between (001)-CMS and (001)-Ag.[4] Not only MR effect but also spin-transfer-torque (STT) induced phenomena such as STT-induced magnetization switching (SIMS) and oscillation (STO) are also interesting topic since large STT effect can be expected by using highly-spin-polarized Heusler compounds. Very recently, we successfully observed large output power of STO (~ 3nW) in the CMS/Ag/CMS device due to large MR effect and STT effect as shown in Fig.2.[6] Because the precession angle of STT we observed was still very low (just 12º), we expect to enhance output power drastically by inducing the large magnetization precession mode in the CMS layer in near future.

In addition to the CPP-type device, current-in-plane type (lateral type) devices using half-metallic Heusler compounds are also interesting to study because multi-terminality can be realized easily in a lateral device. We fabricated the lateral type spin valve device with consists of two CMS wires (one is spin-injector and the other one is detector) and a nonmagnetic Ag channel wire. It is still preliminary result but we observed large spin-accumulation signal ΔR_s of 7.2 mΩ at RT in the Ag wire. To inject highly spin-polarized current or pure spin current from half-metals to semiconductors in the lateral device is an important subject for realizing new spintronic applications such as spintransistor.

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[3] T. Iwase *et al.*, *Appl. Phys. Express.* **2** (2009) 063003.
[4] Y. Sakuraba *et al.*, *Phys. Rev. B* **82** (2010) 094444.
[5] Y. Sakuraba *et al.*, *J. Phys.D* **44** (2011) 064009.
[6] R. Okura *et al.*, *Appl. Phys. Lett.* **99** (2011) 502510.

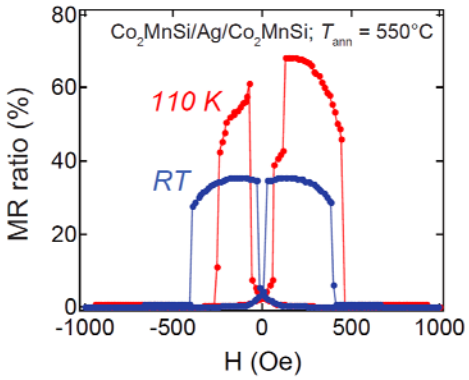

Fig.1 MR curves in the CMS/Ag/CMSz device.

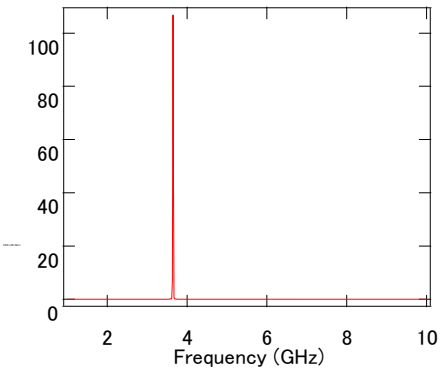

Fig.2 rf spectrum in the STO measurement in the CMS/Ag/CMS device.