RB04

Effects of Spin-flip Tunnelling on Temperature and Voltage Dependence of TMR

I. Takada[1], H. Itoh[2], and J. Inoue*[1]
[1]Department of Applied Physics, Nagoya University, Nagoya 464-8603, Japan
[2]Department of Pure and Applied Physics, Kansai University, Suita 564-8680, Japan
*Corresponding author: inoue@nuap.nagoya-u.ac.jp, Phone: +81 52 789 4445, Fax: +81 52 789 3298

Tunnel magnetoresistance (TMR) with high TMR ratio is a crucial ingredient for spintronics devices. A promising way to achieve the high TMR ratio is to utilize the so-called half-metals as electrodes in the ferromagnetic tunnel junctions (FTJs). Half-metallic FTJs have been first fabricated by using perovskite Mn-oxides, and a high TMR ratio has been reported at low temperatures [1, 2]. However, the TMR ratio decreases rapidly with increasing temperature and becomes almost zero below the Curie temperature (T_C) of Mn-oxide. Since TC of perovskite Mn-oxides is around the room temperature, device application of these FTJs may not be realized. The high TMR ratio observed in epitaxicial Fe/MgO/Fe and polycrystalline FeCoB/MgO/FeCoB junctions may also be attributed effectively to a half-metallic feature due to spin filtering of spin-polarized current through the MgO barrier [3, 4].

Recently Heusler alloys attract much interest since they have T_C much higher than the room temperature. Actually, by using a full Heusler alloy inFTJs, nearly 500% TMR ratio has been achieved at 4.2K [5]. The TMR in these FTJs, however, also shows strong temperature and voltage dependence, which have been attributed to rather small band gap in the minority spin state of the Heusler alloy.

Because the TMR ratio at the room temperature is the essential ingredient for the device application of FTJs, a crucial issue may be raised whether the strong decrease in the TMR ratio with increasing temperature is of intrinsic or extrinsic origin. In order to approach the issue, we will adopt a phenomenological theory [6] whichincorporates the spin-flip tunnelling into calculations and study the temperature and voltage dependence of the TMR ratio by introducing magnetic coupling between tunnelling electrons and localized spins. We find that rather strong dependence of TMR on temperature and voltage appears when the effective Curie temperature of localized spins is low. The calculated results are compared with experimental ones by changing the parameter values toexamine if the strong temperature and voltage dependence is of intrinsic or extrinsic.Discussions on the electronic structure of Heustler alloys will also be presented.

We acknowledge financial support from the Next Generation Super Computing Project, Nanoscience Program, and the 21st Century COE Program "Frontiers of Computational Science".

REFERENCES
[1] Yu Lu et al., Phys. Rev. B **54**, R8357 (1996).
[2] M. Bowen et al., Appl. Phys. Lett. **82**, 233 (2003).
[3] S. Yuasa et al., Nat. Mater. 3, 868 (2004).
[4] S. S. P. Parkin et al., Nat. Mater. 3, 862 (2004).
[5] Y. Sakuraba et al., Jpn. J. Appl. Phys. **44**, L1100 (2005).
[6] J. Inoue and S. Maekawa, J. Magn. Magn. Mater. **198-199**, 167 (1999).

RB05

Tunnel Mgneto Rsistance in MTJs with Eitaxially Gown Heusler Alloy Elecrodes

M. Oogane*[1], M. Hattori[1], Y. Sakuraba[1], Y. Ando[1] and T. Miyazaki[1]
[1]Department of Applied Physics, Tohoku University, Aoba-yama 6-6-05, Sendai, 980-8579, Japan
*Corresponding author: oogane@mlab.apph.tohoku.ac.jp, Phone: +81 22 795 7949, Fax: +81 22 795 7947

Heusler alloys have attracted great interest because they are expected to have large spin-polarization (P). Such materials possess large potential use in spin electronics devices such as magnetic random access memory (MRAM). Magnetic tunnel junctions (MTJs) with Heusler alloy electrodes lead to large magnetoresistance (MR) ratio because MR ratio is strongly concerned spin-polarization of ferromagnetic electrodes of MTJs. Co2MnSi, a kind of Heusler alloy, is expected theoretically to exhibit half metallic band structure (P = 1). Recently, we succeeded to fabricate a MTJ with (100)-oriented epitaxial Co2MnSi electrode this MTJ exhibited large MR ratio of 70% at RT and 159% at 2 K, respectively [1]. This result indicates that Co2MnSi(100) has half-metallicity, however, the MTJ showed large temperature and bias voltage dependence of MR ratio. In this research,we fabricated the MTJs with (110) and (211)-oriented epitaxial Co2MnSi electrodes and investigated the MR effect in the MTJs in order to improve temperature dependence of MR ratio.

The samples were prepared by magnetron sputtering onto Sapphire (for (110)) and MgO (for (211)) substrates in ultrahigh vacuum chamber. Crystal structure and surface morphology for the Co2MnSi and buffer layers were analyzed by X-ray diffractmeter (XRD) and atomic force microscope (AFM). The saturation magnetization was measured by vibrating sample magnetometer (VSM). Magneto resistance was measured by dc four-probe method.

Temperature dependence of the MR ratio for the MTJswith $Co_2MnSi(110)$ and $Co_2MnSi(100)$ are shown in Fig. 1. Typical magneto-resistance curve measured at 2 K for the MTJ with Co2MnSi(110) is shown inset of Fig. 1. For the MTJ with Co2MnSi(110) electrode, MR ratio was 40% at RT and 120% at 2K, respectively. Temperature dependence of the MR ratio for the $Co_2MnSi(110)$-MTJ was almost similar to that of the $Co_2MnSi(100)$-MTJ. However, we observed different dV/dI-V characteristics in parallel magnetic configuration between the $Co_2MnSi(110)$- and the $Co_2MnSi(100)$-MTJs. The dV/dI-V result reflects the difference of electronic band structure of $Co_2MnSi(100)$ and $Co_2MnSi(110)$.

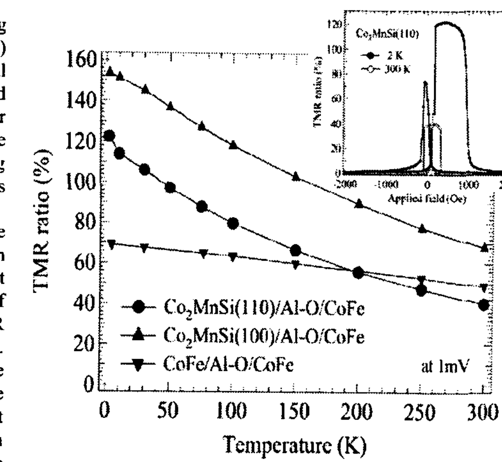

Fig. 1. Temperature dependence of the MR ratio for the MTJs with $Co_2MnSi(110)$ and Co2MnSi (100). Inset shows MR curve for the MTJ with Co_2MnSi (110) electrode. for the MTJ with Co2MnSi(110) measured at 2 K.

REFERENCES
[1] Y.Sakuraba, J. Nakata, M. Oogane, H. Kubota, Y. Ando, A. Sakuma, T. Miyazaki, Jpn. J. Appl. Phys. **44**, L1100 (2005).